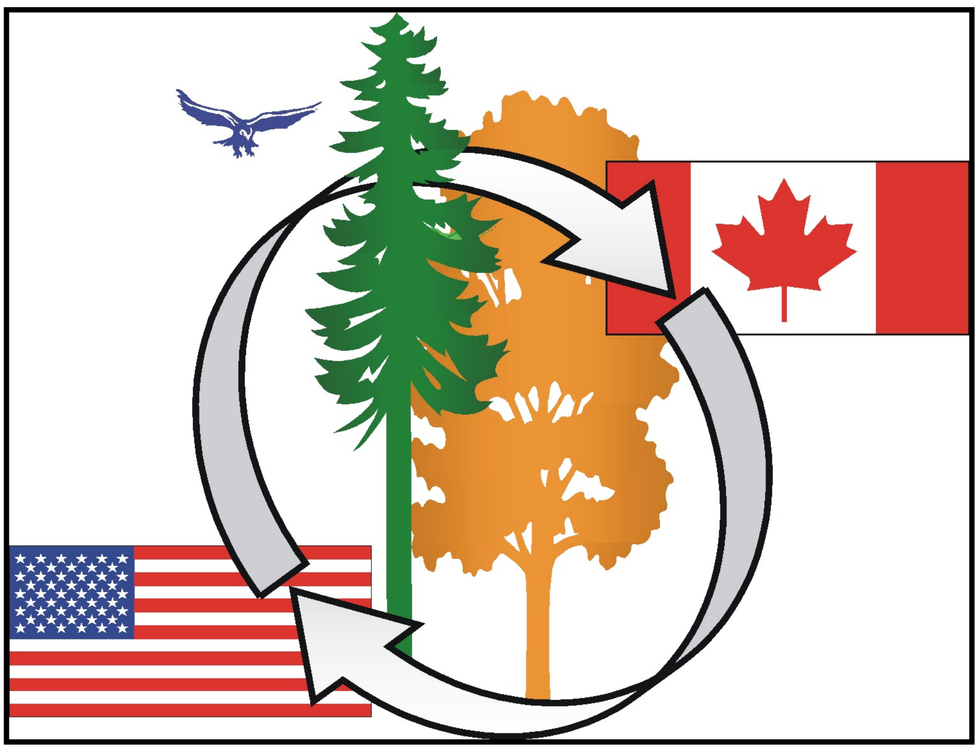
Colloque Eastern CANUSA

Les sciences forestières au-delà des frontières

Eastern CANUSA Conference

Forest Science across the Borders

19-21 octobre 2006 / October 19-21, 2006
Université Laval, Pavillon Alphonse-Desjardins
Québec (Québec) / Quebec, QC
Canada



Manuel de conférence

Seconde édition avec résumés populaires

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Ressources naturelles Canada | Natural Resources Canada
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Québec

Université Laval
Faculté de foresterie et de géomatique

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Compilé par / Compiled by

Guy R. Larocque
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Organisé par :
Hosted by:

Natural Resources Canada
Canadian Forest Service

Ministère des Ressources naturelles et de la Faune du Québec
Direction de la recherche forestière

Université Laval
Faculté de foresterie et de géomatique

Ressources naturelles Canada / Natural Resources Canada
Canada

Ressources naturelles et Faune
Québec

Université Laval
Faculté de foresterie et de géomatique

MOT DES ORGANISATEURS

C'est avec grand plaisir que nous vous souhaitons la bienvenue à l'Université Laval, Québec, pour le troisième Colloque Eastern CANUSA sur les sciences forestières. Cette année, le Colloque Eastern CANUSA est organisé conjointement par le ministère des Ressources naturelles et de la Faune du Québec – Direction de la recherche forestière, Ressources naturelles Canada – Service canadien des forêts et l'Université Laval – Faculté de foresterie et de géomatique.

Comme vous le savez, les régions du nord-est des États-Unis et de l'est du Canada se partagent une zone forestière commune et vitale. En plus d'une forte interdépendance économique, les populations de ces régions tirent des avantages considérables de cette vaste zone forestière. C'est pourquoi le devenir de ces régions repose indiscutablement sur la gestion durable de cette ressource forestière de grande valeur. En raison de l'importance de ces forêts, les aménagistes et les chercheurs forestiers des États du Nord-est et des provinces de l'est du Canada cherchent constamment des solutions aux défis reliés à l'aménagement des ressources naturelles. Comme beaucoup de travaux sont réalisés des deux côtés de la frontière canado-américaine, il est essentiel d'accroître les échanges d'information sur les connaissances acquises sur ces forêts du Nord-est. C'est donc dans cet esprit qu'est né le Colloque Eastern CANUSA sur les sciences forestières. Organisé tous les deux ans, ce forum s'est tenu une première fois à l'Université du Maine en 2002 et une seconde fois à l'Université du Nouveau-Brunswick en 2004.

Les objectifs du colloque sont : 1) de favoriser les communications des deux côtés de la frontière sur les plus récents enjeux d'aménagement et de recherche forestière; 2) de fournir une tribune permanente d'échange d'information entre les gestionnaires et les chercheurs canadiens et américains du domaine forestier; 3) de fournir une tribune aux étudiants des trois cycles universitaires qui travaillent sur des problèmes forestiers connexes, afin qu'ils puissent y présenter les résultats de leurs recherches, rencontrer d'autres chercheurs et étudiants travaillant sur des problèmes similaires et être informés des problèmes forestiers de ces régions; et 4) de susciter le rapprochement des chercheurs, des étudiants et des praticiens sur les problèmes forestiers communs des deux côtés de la frontière.

Nous vous souhaitons donc un excellent colloque. Nous espérons sincèrement que les présentations de nos conférenciers contribueront à améliorer vos connaissances et votre pratique professionnelle. Enfin, nous souhaitons que vous puissiez établir de nouvelles relations professionnelles et amorcer de nouvelles collaborations pour les années à venir.

A WORD FROM THE ORGANIZERS

It is with great pleasure that we welcome you to Université Laval, Quebec City, for the third au Eastern CANUSA Forest Science Conference. This year, the Eastern CANUSA Conference is organized jointly by the ministère des Ressources naturelles et de la Faune du Québec – Direction de la recherche forestière, Natural Resources Canada – Canadian Forest Service, and Université Laval – Faculté de foresterie et de géomatique.

As you know, the northeastern United States and Eastern Canada share a vital and common link with the northern forest. In addition to a strong economic interdependence, people from these regions derive considerable benefits from this forest. Hence, the future of these regions clearly relies upon the sustainable management of this highly valued forest resource. Because of the importance of the northern forest, forest managers and researchers from the northeastern States and eastern Canadian provinces are working continuously to find solutions to a wide variety of issues related to natural resources management. Important work is being carried out on both sides of the US/Canadian border that would be further enhanced by regular information exchange on the knowledge gathered on the northeastern forest. With this thought in mind, the Eastern CANUSA Forest Science Conference was created with the objective of organizing a conference every two years. The first Conference was held in 2002 at the University of Maine, and the second was hosted by the University of New Brunswick in 2004.

The conference objectives are: 1) to promote cross-border communication about the latest forest management and research issues; 2) to provide a regular forum for information exchange between US and Canadian forest managers and researchers; 3) to provide a forum for graduate and undergraduate students working on forest-related issues so that they may present their research findings, meet other forest scientists and students working on similar issues, and gather information on northeastern forest issues; and 4) to bridge the gap between researchers, students and policy makers about natural resources issues common to both sides of the border.

We wish you an excellent conference, and we sincerely hope that our speakers' presentations will help improve your knowledge and practice. We also hope that you will establish new professional relationships and form new partnerships for the years to come.

REMERCIEMENTS

Cette conférence a vu le jour grâce à la contribution de plusieurs personnes, en commençant par les conférenciers qui ont fait état de leurs connaissances sur les questions discutées et qui ont bien voulu les résumer pour les besoins du présent recueil.

Nous aimerions aussi témoigner notre reconnaissances aux personnes qui ont participé au soutien logistique : mesdames Marie Pothier, Michelle Poulin et Diane Paquet de Ressources naturelles Canada, mesdames Diane Bélanger, Élaine Paris, Maripierre Jalbert, Ginette Lagacé, Loraine Parent et Denise Duchesne ainsi que monsieur Clément Gaudreau du ministère des Ressources naturelles et de la Faune du Québec.

Nos remerciements vont également aux participantes et aux participants provenant de différentes régions du Canada et des États-Unis.

Le comité organisateur de la conférence

ACKNOWLEDGEMENTS

This conference was made possible thanks to the contribution of several persons, beginning with the speakers who shared their knowledge on the topics discussed and were willing to summarize this knowledge so that it could be presented in this document.

We also thank the following persons for their logistical support: Marie Pothier, Michelle Poulin and Diane Paquet of Natural Resources Canada; Diane Bélanger, Élaine Paris, Maripierre Jalbert, Ginette Lagacé, Loraine Parent, Denise Duchesne and Clément Gaudreau of the ministère des Ressources naturelles et de la Faune du Québec.

We sincerely thank all the participants who came from different regions of Canada and the United States.

The organizing committee of the conference

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Field trips
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Evelyn Thiffault – Faculté de foresterie et de géomatique, Université Laval

Field trips :
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Sébastien Meunier – Ministère des Ressources naturelles et de la Faune
Rock Ouimet – Ministère des Ressources naturelles et de la Faune

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8:45 to 9:25	Carbon cycling and trophic dynamics in forests exposed to elevated CO_2 – ***Room Hydro-Quebec*** Speaker: Dr. Evan DeLucia – University of Illinois, Illinois, USA
9:25 to 10:05	Collective Conservation in the Northern Appalachian/Acadian Ecoregion – ***Room Hydro-Quebec*** Speaker: Williams Ginn – The Nature Conservancy, Maine, USA
10:05 to 10:35	Break – ***Agora of Pavillon Alphonse-Desjardins***
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11:15 to 11:55	Looking at the future, forest and socioeconomic development in Quebec – ***Room Hydro-Quebec*** Speaker: Dr. Luc Bouthillier – Université Laval, Québec, Canada
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8:30 to 10:10	Concurrent Technical Sessions (5 X 20 minutes) -Forest Ecosystems – ***Room Hydro-Quebec*** -Silviculture – ***Room 2320*** -Tree physiology, carbon and nutrient cycles and genetics – ***Room 2326*** -Forest management, operations and engineering – ***Room 2300***
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12:00	Banquet lunch and closing remarks **–** ***Le cercle Pavillon Alphonse-Desjardins***

FIELD TRIPS
THURSDAY, OCTOBER 19

Field Trip 1 — Duchesnay Tourist Station — Ecosystems and Environment
Nutrient cycle and maple dynamics in the Lac Clair watershed, Duchesnay Experimental Forest

During this trip, conference attendees will have the opportunity to visit the monitoring experiments being carried out at the Lac Clair forest watershed, one of the most studied forest ecosystems in eastern North America. Visitors will have the opportunity of seeing for themselves how biochemical, biogeochemical and geochemical cycles in the watershed are measured, as well as the consequences of disturbing the cycles, structure and composition of the maple stands. The important atmospheric acid inputs are a major stress factor. Calcium is a key limiting mineral in this ecosystem. The soil processes involved will be explained and the experimental soil amendment trials will be discussed, where results show the importance of calcium in maintaining the growth and health of sugar maple.

Field Trip 2 — Duchesnay Tourist Station — Silviculture

In Québec, selection cutting was first practised on an experimental basis starting in the early 1980s. In order to study forest dynamics following this silvicultural treatment, several experimental blocks were established in several regions in southern Québec by the Direction de la recherche forestière in the ministère des Ressources naturelles et de la Faune. The Duchesnay Tourist Station is part of a provincial forest research network, and has 11 experimental blocks. Two of the blocks, established in 1992 and 1994, will be observed during this visit. Mortality, growth, ingrowth and stand quality and structure will be among the subjects discussed.

Keynote presentations

Carbon cycling and trophic dynamics in forests exposed to elevated CO_2

DeLucia, Evan H.[1*], John E. Drake[2] and Richard J. Norby[3]

[1]Department of Plant Biology, University of Illinois, Urbana, Illinois, USA
[2]Program in Ecology and Evolutionary Biology, University of Illinois, Urbana, Illinois, USA
[3]Environmental Science Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee, USA

Introduction

Prior to the mid 19th century the global carbon cycle was largely in balance, the removal of CO_2 from the atmosphere by photosynthesis was approximately equal to its return by plant and microbial respiration, and the concentration of CO_2 in the atmosphere was stable at or below ~280 ppm. With the accelerated mining and combustion of fossil fuels during the Industrial Revolution and continuing today, the concentration of atmospheric CO_2 is dramatically rising. Combined with widespread deforestation, current use of fossil fuels has accelerated this trend. Now at 380 ppm, current projections are that atmospheric [CO_2] will exceed 550 ppm by 2050 and continue to increase from there. The accumulation of CO_2 and other radiatively active "greenhouse" gasses in the atmosphere is driving an unprecedented rate of global warming. In addition, the photosynthetic pathway of trees is not saturated at current levels of CO_2, so increasing photosynthesis may stimulate carbon cycling and productivity of the biosphere. Until recently this hypothesis was untested.

By regulating the exchange of CO_2 with the atmosphere, forests play a central role in the global carbon cycle. Approximately half of global net primary production (NPP) and 80% of terrestrial NPP is attributed to forests.[1] It had been hypothesized that a stimulation of forest productivity by elevated CO_2 may substantially slow its accumulation in the atmosphere. In fact, the concentration of CO_2 is increasing less that would be expected from known rates of emission and uptake, and it has been postulated that this fertilization effect might account for the "missing carbon sink." While it is well established that elevated CO_2 stimulates photosynthesis and growth of seedlings and small trees in enclosures, until recently it was not possible to conduct an experiment at an appropriate spatial scale to examine the CO_2 effect on an intact forest that experiences natural climate variation and interacts with the natural biogeochemical cycles of limiting mineral nutrients.

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[*] http://www.life.uiuc.edu/delucia/index.htm
[1] DeLucia, E.H. et al. 2005. *Global Biogeochemical Cycles* 19:GB3006,doi:10.1029/2004GB002346.

By releasing measured quantities of CO_2 into the canopies of large plots (25-30 m diameter) in intact forests, Free Air CO_2 Enrichment (FACE) technology provides the ability to examine the responses of biogeochemical processes, including carbon and nitrogen cycling, in a forest ecosystem to future levels of this important trace gas. Here, we will present the central conclusions from FACE experiments conducted in four different forest types, the implications of these results for the global C cycle, and some important questions that remain.

FACE and forest productivity

From 1996 to 1999 four FACE experiments were initiated in different locations and with different tree species (loblolly pine plantation, *Pinus taeda* North Carolina, USA; sweetgum plantation, *Liquidambar styraciflua*, Tennessee, USA; mixture of aspen and birch, *Populus tremuloides and Betula papyrifera*, Wisconsin, USA; assemblage of different poplar species, *Populus alba, P. nigra, P. x euramericana*, Tuscania, Italy). Because they used different species and were in different climates, NPP in these forests ranged from less than 500 gC m^{-2} y^{-1} to more than 2000 gC m^{-2} y^{-1}; this is approximately the range in NPP of forests world-wide. Each of these experiments exposed intact forest plots to approximately 550 ppm, the projected level for 2050.

The response of NPP in these forests to elevated CO_2 was remarkably similar; at the median value NPP was stimulated by 23%.[2] Before the canopies in these forests reached their maximum leaf area, elevated CO_2 stimulated NPP by increasing light interception; as canopies approached their maximum leaf area elevated CO_2 increased efficiency of the conversion of light energy into new biomass. There were dramatic differences in where new carbon was allocated among forest types and these differences may affect how long it is stored before being returned to the atmosphere. The pine forest, for example, responded to elevated CO_2 by allocating new carbon to stem growth, while the sweetgum forest invested virtually all new carbon in the production of fine roots. Given how rapidly fine roots decompose, much of the new carbon in the sweetgum forest might be returned to the atmosphere in a year or two after being fixed.

Results from the FACE experiments indicate that NPP in young forests will increase by approximately 23% as CO_2 increases to 550 ppm over the next few decades. However, the magnitude of stimulation is too small to offset the projected emissions of CO_2 by anthropogenic factors and will have a smaller effect on the global carbon cycle than changes in land use. If we assume that all temperate forests will experience a 23% increase in NPP and retain the same ratio of NEP/NPP as the loblolly pine forest, ~1.5 PgC $year^{-1}$ will be sequestered. This optimistic estimate still represents less than 10% of the global emissions of fossil fuel CO_2 predicted for 2050. It is clear that the terrestrial forest sink cannot completely mitigate atmospheric change. Furthermore, while the regrowth of forests in eastern North America over the past 150 years has contributed significantly to the aforementioned “missing sink,” global deforestation is seriously degrading the capacity of terrestrial ecosystems to sequester carbon and slow its accumulation of in the atmosphere.

[2] Norby, R.J. et al. 2005. *Proc. Natl. Acad. Sci. USA* 102:18052-18056.

Changes in foliage quality and herbivory

It has been hypothesized that as sugars and starch accumulate and proteins becomes diluted in leaves exposed to elevated CO_2, insects that feed on foliage will consume more to meet their nutritional demands. By providing unfettered access to insects and pathogens, FACE experiments provide a unique opportunity to test what is now referred to as the compensatory feeding hypothesis. While the data are insufficient to provide a definitive test of this hypothesis, early results are intriguing.

An examination of more than a dozen hardwood species that established in the understory of a pine forest revealed that the amount of leaf tissue removed by insect herbivores was lower for saplings exposed to elevated compared to ambient CO_2 – the opposite of the compensatory feeding hypothesis.[3] The reduction in herbivory may be related to an increase in the carbon:nitrogen ratio of leaf tissue or, at least for some of the oak species, and increase in the concentrations of tannins under elevated CO_2. It is interesting to note that in a similar experiment conducted with soybeans, damage by leaf-feeding insects greatly increased for plants exposed to elevated CO_2.[4] With the limited data at hand the only reasonable conclusion is that this element of global change will affect the trophic dynamics in ecosystems by causing fundamental changes in leaf chemistry.

Uncertainties and Unresolved Questions

While the 23% stimulation in NPP provides a benchmark for efforts to model aspects of forest and global carbon cycles, a number of important uncertainties exist. Perhaps foremost among these uncertainties is the sustainability of the response observed in these fairly young forests. The one experiment conducted to date with old-growth trees indicates their physiological responses to elevated CO_2 were similar to those observed in the FACE experiments discussed above. However, replication in this experiment was inadequate to detect a growth response.[5] While the magnitude varies from year to year, there is no evidence yet of a loss of the growth stimulation in the pine FACE experiment, the longest running for the four forest experiments.[6] Nitrogen uptake generally is greater in forest plots exposed to elevated CO_2, and no effect on nitrogen-use efficiency has been detected.[7] It seems reasonable to speculate that with time, limited capacity of the soil to provide nitrogen and other nutrients will constrain the growth stimulation caused by elevated CO_2.

Results from these FACE experiments tell only part of the story. As CO_2 increases from current levels to 550 ppm, global mean temperatures will increase by 4-6 ^oC. The potential interaction of warming with elevated CO_2 on forest productivity has not been addressed in the current FACE experiments and is technically daunting. An examination of inter-annual variation in the response to elevated CO_2 offers a clue to how these components of global change may interact. At the pine FACE experiment, elevated CO_2 caused the greatest percentage stimulation of NPP

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[3] Knepp, R.G. et al. 2005. *New Phytologist* 167(1):207-218.
[4] Hamilton, J.G. et al. 2005. *Environmental Entomology* 34:479-485.
[5] Korner, C. et al. 2005.*Science* 309:1360-1362
[6] Moore, D.J.P. et al. 2006. *Global Change Biology* 12:1367-1377.
[7] Finzi, A.C. et al. 2006. *Ecology* 87:15-25.

in warm and dry years.[5] Absolute NPP was lower during these years than in cooler, wetter years, but the reduction was not as great for trees exposed to elevated CO_2. This responses is consistent with physiological theory but to date it is unknown if other forests act similarly. More importantly, warming may stimulate decomposition causing most if not all new carbon to be respired rapidly back to this atmosphere. One of the FACE experiments includes an interaction with elevated ozone but the interactions with other environmental factors, particularly precipitation, remain unknown.

The similar response to elevated CO_2 among the four forests described above may not necessarily represent an overarching response that can be generalized to all forest types but instead may reflect that these experiment used tree species with similar life history traits. While phylogenetically distinct, pine, aspens and birches are early successional species and as such are fast growing, responsive to fertilization and intolerant of shade. Similarities in their underlying physiology may have contributed to their convergent responses to elevated CO_2. How boreal forest and tropical forest, both young and old, respond to elevated CO_2 remain unknown. Answering these questions represent a considerable challenge to forest ecologists and physiologist.

Conclusion

Free Air CO_2 Enrichment (FACE) technology has for the first time permitted the experimental manipulation of the atmosphere in intact forest plots. Results from four ongoing FACE experiments suggest that exposure to the level of CO_2 predicted for the year 2050 will stimulate NPP in young forest by 23%. A stimulation of global forest productivity by this amount is insufficient to offset the rise in atmospheric CO_2 and abate global warming. Faced with widespread deforestation, it would appear that controlling the emission of CO_2 to the atmosphere holds the greatest promise for slowing the rate of global warming. In addition to directly affecting forest productivity, CO_2-induced changes in leaf chemistry will affect the amount of leaf tissue removed by herbivores and will thus influence the trophic structure of forests in the future. How the response of forest to elevated CO_2 will be modulated by other climatic factors and pollutants, as well as N deposition and different forest types will respond remain important unanswered questions.

Acknowledgements

The authors gratefully acknowledge the U.S. Department of Energy, Office of Science, Biological and Environmental Research Program for their support of this research.

Collective Conservation in the Northern Appalachian/Acadian Ecoregion

William J. Ginn

Global Forest Partnership, The Nature Conservancy, 90 Minot Road, Pownal, ME 04069, USA. wginn@tnc.org.

The Northern Appalachian/Acadian Ecoregion is an 82 million-acre landscape extending across four states in the northeastern United States, three Canadian maritime provinces and the portion of Quebec from the St. Lawrence River southward. It is a region of immense physical diversity, from windswept alpine mountains to rugged rocky shorelines. Almost entirely forested, the region contains a wide range of bedrock types, landforms, elevation gradients and an estimated 3,844 species of mammals, reptiles, amphibians, birds, plants and macro-invertebrates. (See Figure 1- Map of the Northern Appalachian/Acadian Ecoregion)

In a region that has a 400+ year history of settlement and a legacy of intensive management, identifying the critical areas of the region that, if conserved, would result in maintaining all of the region's native species, ecosystems and dynamic process is a complex analysis. In 1999, The Nature Conservancy embarked on the creation of a plan for identifying such a set of conservation priorities in the region. It quickly became apparent that our initial efforts were inadequate to the task. For one, the data sets used in the analysis focused only on the US portion of the region and ignored Canada's contributions, and for another, failed to address critical questions such as, How big should reserves be? How do we maintain connectivity across the region for wide-ranging species such as lynx and Atlantic salmon? Clearly a more robust analysis of these factors was needed to obtain a more complete picture of the region's assets and to develop a strategy for conservation.

An added complexity to this analysis was the limited cross-border communication between conservation groups that existed at the time. U.S. conservation groups called this region the "northern forest" but to Canadians such a term more appropriately referred to the boreal region. From the perspective of Quebec, the region south of the St. Lawrence was the "southern forest." Cultural barriers and geo-political factors completed the confusion. In 2000, the Henry P. Kendall Foundation, of Boston, with the support of the ELJB Foundation, in Montreal, hosted the first-ever meeting of conservation groups working in the region. From the beginning it became clear that we shared common goals around conservation and that only through collaboration could Canadian and U.S. goals for protection of the region's biodiversity be achieved.

Over the course of the last six years, an increasingly strong and effective network of conservation groups sharing scientific data and strategy has emerged. At the center of this work is Two Countries, One Forest—Deux Pays, Une Forêt (2C1Forest)[i]. From a small office initially in Boston, and now in Halifax, the organization has served as a catalyst for collaborative conservation across the region. With the support of this network, a newly revised conservation assessment of the region has been published and three other major conservation-related studies are nearing final preparation.[ii] These include a detailed assessment of the human footprint in the region; an analysis focusing on critical ecological connections needed to maintain populations of wide-ranging species; and, an assessment of the future human footprint based on different policy and growth assumptions in the region. The last study is being presented at this year's ECANUSA meeting by Stephen Trombulac and Robert Baldwin.

For those of you thinking of cross-border work of this nature, I would like to highlight some of the challenges in completing this work. Agreeing on the physical dimensions of the region and the sub-regional boundaries proved to be surprisingly complex. TNC uses a modified version of Bailey's ecoregions in outlining the boundaries, while much of Canada uses ecoregions established under work of the World Wide Fund for Nature (WWF). A second challenge was gaining access to data layers for the region. Much of the region's data is held by government agencies, but even in states and provinces some data is held by wildlife agencies and others by forest or conservation departments. Also, excellent data was often in the hands of large private landowners and leaseholders who were initially suspicious of the motives of our investigators. Small differences in physical resolutions of data sets, road types and in the definition of landforms and bedrock geology resulted in a dauntingly complex cross-walking of information to present a seamless picture of even the physical borders of the region.

Even determining the conservation status of lands proved to be complex. In the United States, National Forests confer significant protection. For example the Adirondack state park lands are constitutionally required to be maintained in a forever-wild status. In Canada, however, the future status of "crown lands" is less secure under provincial leasing to timber and mining concessions for very long periods. In this region, 29 million acres, or 36%, is secured against conversion to development but is managed for intensive forest harvesting, while only 7% is explicitly managed for biodiversity. It was a learning experience on both sides of the border as we contemplated how to correctly categorize "national forests" in the United States and "crown lands" in Canada. (See Figure 2- Map of Areas Permanently Secured Against Conversion to Development).

The collective scientific discourse of the last few years is bearing fruit, and while a complete examination of the results of these papers must await another forum, I would like to share with you some of the results from the TNC/NCC ecoregional assessment to illustrate the rich body of work now available. One of the dominate features of this landscape is the matrix forest areas. This region is the most intact forested area in the eastern United States and Canada. A study of the region identified the areas with at least 25,000 acres or more of contiguous forest cover. More than 80 such blocks were identified, with 10 of them exceeding half a million acres in size. The largest block, covering most of the Northern Appalachian/Acadian region, was more than 44 million acres in size. This makes the region the most ecologically intact area in the eastern United States and in Canada south of the boreal zone.

At the same time, it's not enough to just say "conserve it all." To determine a subset of this ecoregion that would capture the breath of diversity of forest types, the team looked at ecological sub-regions, underlying geological factors and forest type to come up with a recommended set of areas on which to focus conservation activity. Intuitively, the rocky granite mastiffs of the Gaspé or Mt. Katahdin are quite different from the calcareous slopes of the St. John River Valley or Lake Champlain, and the maritime climatic influences in Nova Scotia make these forests distinct from the Adirondacks. The assessment identified 178 critical forest blocks representing 25,000 acres or more of forest and the full range of forest types in the region. Today, 28% of these forest blocks contain protected areas greater than 25,000 acres, ranging from a high of 71% protected in New York to a low of 13% protected in Maine. (See Figure 3 Matrix Forest Blocks of the Region by Type).

To protect a representative portfolio of all of the communities and species present in the region is a challenging task. First, we need to ensure that all of the critical places have protection at a level that secures their ecological viability. Second, we need to abate critical threats to the region that cannot be addressed through land conservation – threats such as climate change, invasive species and airborne toxins that all affect the biological integrity of the region.

The region is undergoing dramatic change. In the United States, the sale of more than 10 million acres of timberlands by long-term industry owners to investors has increased the potential for development and unsustainable forest practices. The carving up of these lands into parcels and other fragmentation is also increasing, especially in the United States, as land is sold for second-home development. In addition, the ecoregion as a whole is being significantly affected by atmospheric pollution that threatens a wide range of plant and animal populations and is reducing the productivity of the region's forests. The region is also vulnerable to invasive forest pests and pathogens, some of which, if unchecked, could create widespread species loss and cascading community effects rivaling the chestnut blight and Dutch elm disease of earlier eras. Finally, climate change over the next hundred years is predicted by some models to dramatically alter forest composition as spruce-fir trees shift northward and hickory-oak forests proliferate in the southern portion of the region. These changes have the potential for major ecological as well as economic impacts. The traditional timber products backbone of the region already faces major market changes even without these other potential impacts.

Recently, the U.S. Department of Agriculture released the findings of a multi-year study of eastern forests. Of the top 15 watersheds predicted to experience dramatically increased housing densities, four are all or partially within the Northern Appalachian/Acadia Ecoregion.[iii]

Even in those areas where timber production is likely to continue over the next 100 years, forest management is affecting the biodiversity of the region. Marketplace changes continue to favor small-diameter wood production (as engineered products replace whole lumber). This, along with increased pressure for improved financial returns, is expected to favor shorter-rotation lengths in managed forests in the region. Ecologically, as opposed to silviculturally, mature stands are likely to disappear from the landscape unless explicitly protected. In New Brunswick, 75% of the forests were 80 years old or older in the early 1970s. Today that number has declined to 45%.

In addition, the area is now extensively connected with roads built since the late 1960s, the decade marking the end of water transport of logs. This extensive road network opens access to lakes and rivers, increasing development pressure and recreational use and also increasing the potential introduction of non-native species.

A more insidious threat to the region comes from atmospheric pollution—mostly from the burning of coal in the Midwest, but also from automobile pollution. Researchers at Hubbard Brook have carefully documented the impacts of many of these changes and have found acid precipitation has altered soils in areas of the northeastern United States and eastern Canada.

These changes have resulted in significant new stresses to trees in areas of the region. Recent research shows that acid deposition has contributed to the decline of red spruce trees throughout the eastern United States and sugar maple trees in central and western Pennsylvania. Instances of dieback and deterioration have been noted in white birch in southeastern New Brunswick as a result of acid fog. Symptoms of tree decline include poor tree crown condition, reduced tree growth, and unusually high levels of tree mortality.

Acid deposition has also impaired the water quality of lakes and streams. Recent water quality data show that 41% of lakes in the Adirondack Mountains of New York and 15% of lakes in New England exhibit signs of chronic and/or episodic acidification, while 30% of the lakes in the Maritimes have become acidified as a result of acidic deposition.[iv]

Other studies have raised concerns about impacts on humans and wildlife from atmospheric deposition of pollutants. Several states including Maine have health warnings on consuming wild fish because of levels of mercury and other pollutants. The Biodiversity Research Institute, in Falmouth, Maine, has been studying mercury levels in loons since 1994. Some 20% to 25% of loons in Maine have high mercury levels, high enough, in fact, that they are at risk of neurological and behavioral problems; those loons fledge 40 percent fewer young. And some tree swallows in Acadia National Park are more mercury-contaminated than birds at a Superfund site in Massachusetts.

Worldwide, invasive species are one of the most significant contributors to species loss. In forested systems, the threats are particularly significant from introduced pests and pathogens on dominant forest trees. The phenomenon is not new in the region. The chestnut blight removed the American chestnut from forests of the region in the 19th century. Dutch elm disease largely extirpated American elm although the impacts were mostly felt in urban areas. Gypsy moths are now a regular cyclical feature of northern hardwoods, with significant outbreaks occurring every 10-15 years. Beech bark disease has now spread from the Maritime Provinces throughout New England. While stressed trees often die from these outbreaks, the impact is limited. However, several new and potentially much more aggressive pests are poised to impact the region. Hemlock woolly adelgid, introduced from Asia, has no known natural predator in North America and is usually 100% fatal to infected trees. So far severe winter temperatures seem to be keeping it from spreading in the ecoregion, but the likelihood of milder winter conditions and the ability of insect populations to rapidly adapt to new conditions make it likely it will move north. Hemlocks are a tree of major economic importance to the region, and if this pest becomes widespread, their loss would have serious ecological and economic ramifications.

In the summer of 2000, Point Pleasant Park in Halifax was infested with the European brown spruce longhorn beetles. By March 2002, more than 2,600 spruce trees in the park were destroyed by authorities to control the insect, and another 1,600 were cut outside the park boundaries. At present, the only control action thought to be effective is to quarantine infested or potentially infested areas and burn the trees. Should quarantine and control efforts fail, the brown spruce longhorn beetle could spread throughout most of the softwood forests of Canada and northeastern United States.

Climate change represents yet another potential for major change in the region over the next 100 years for several reasons. First, temperature changes will favor certain species over others over time, and that will change the ecological context of many parts of the region. Second, climate change is predicted to increase disturbances across the region (hurricanes, for example) that could change the dynamics of stand-replacement events such as wind and ice storms. Climate change will also contribute to sea-level rise, ocean temperature changes and shifts in major ocean currents which will bring significant changes to coastal and marine ecosystems and the species that depend on them. Finally, it is likely that precipitation levels will change. These changes have a high degree of uncertainly about them but it is clear that temperatures will be warmer.

In sum, the region faces many major threats. Some of them are land use in nature and can be addressed by protecting and conserving important areas such as those outlined in this ecoregional assessment. Others are much more insidious and can only be addressed by concerted action at many sites (pests and pathogens, for example), at a policy level (climate change, atmospheric deposition, for example), and by concerted stewardship of protected natural areas (management of recreation, for example).

Since the 1990s, a great deal has been accomplished to implement a new conservation vision for the region. In the United States, 2.5 million acres of forest easements to create critical buffers have been put in place; 500,000 acres of new reserves have been acquired and nearly 8 million acres of forest have been third-party certified under either FSC or SFI systems. Over \$100 million of private capital has matched nearly \$200 million of privately raised or government funds to achieve this result. In Canada, the government of Quebec has committed to creating a new network of protected areas, and in New Brunswick nearly 350,000 acres of new ecological reserves have been established. A new architecture of ownership and protection is slowly emerging across the landscape.

I am convinced that one of the keys to our success will be keeping focused not only on the reserves, national parks and wilderness areas but on the 90% of the landscape where people are part of the equation. Although some of these lands have been heavily altered, 55% at least still exist in a more or less natural state as working forests, grasslands and waterways. Finding the means of giving landowners the incentives to maintain their forests as buffers will be essential to the future viability of much of the world’s biodiversity. The migratory species of this region cannot exist on nesting reserves and over-wintering protected areas alone. All must migrate every year across a landscape occupied by people, and favorable conditions on working farms and forests along the way are required for their survival. Today, countless farmers and foresters wish them well and support their right to be part of the landscape.

The burden on governments to ensure conservation of biodiversity is great. In fact, the Convention on Biodiversity, signed by almost all of the world’s countries (except, sadly the United States), commits the world to setting aside 10% of the globe for conservation. Yet even if governments achieve those goals while adjacent lands are paved by development up to the doors of sanctuaries, no manner of protection will be sufficient to keep natural systems viable. Nature does not respect those limits. Wood is a remarkable fiber — renewable and recyclable. Sustainably managed, it can be the backbone of our housing and, in much of the world, fuel for heating and cooking. Or its potential can be squandered by poor management and illegal harvesting. This fate would force us ever more deeply into a world of synthetics and unsustainable energy-intensive substitutes. Industry will play a critical part in shaping all of this, but so will environmental entrepreneurs who create the policies, regulations and incentives necessary to keep capitalism from consuming itself along with all of nature.

Change will not come easily. Back in 1927, Governor Baxter's plan to protect Mt. Katahdin met with derision from the Maine press. "The silliest proposal ever made to a Legislature was that of Governor Baxter who advocated the State's buying Mount Katahdin and creating a State Park" — or so opined the *Portland Press Herald.*[v] In the end, Baxter pressed forward with his own personal fortune to acquire what is now revered as one of the most inspiring conservation achievements of the 20th century. As we chart our course forward, we will face similar challenges but the summit looms ahead.

To achieve success, the incentives that drive our economy will need to push our boat in the right direction. If poverty dominates much of the rural areas of the region or if consumers show indifference to the source of their purchases, the incentives to cut too much, to intensify our farming and to overburden our land will be overwhelming. If, on the other hand, a global commitment to sustainability becomes the minimum standard for how trees are harvested, farms are managed and communities supported, then there is hope for all.

Figure 1. Map of the Northern Appalachian/Acadian Ecoregion

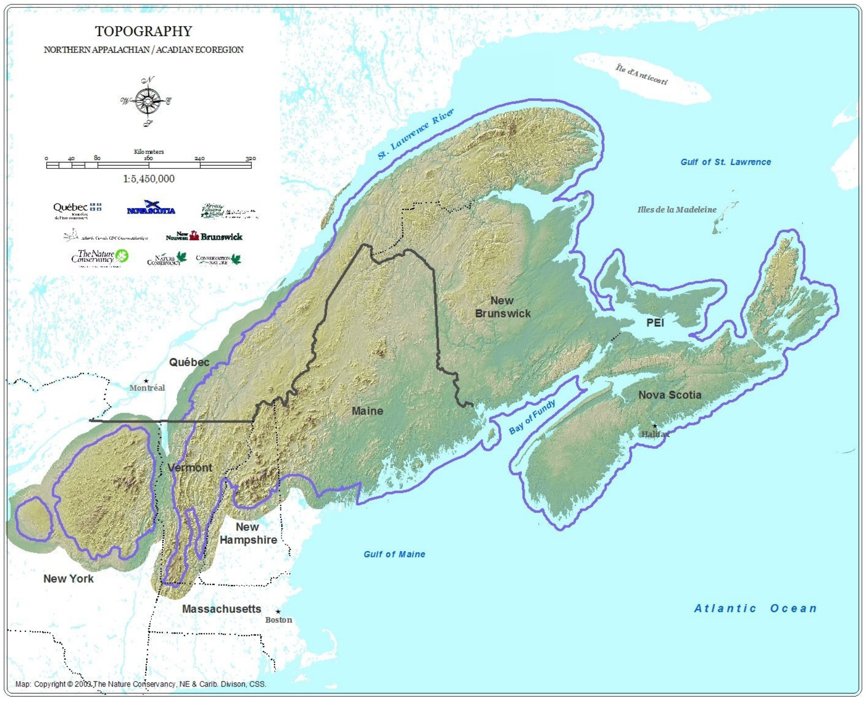


Figure 2. Protected Lands GAP 1-3

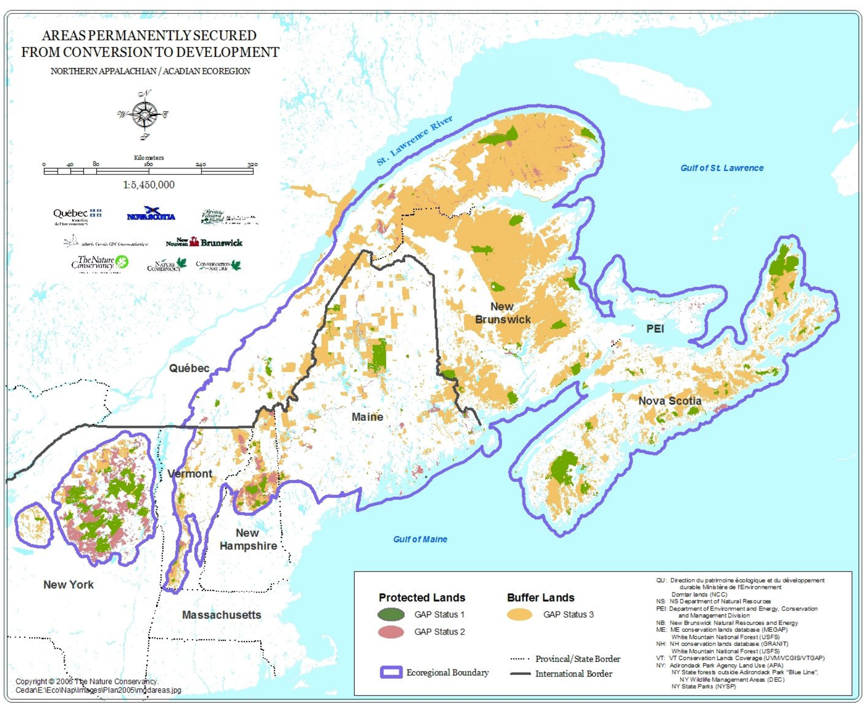
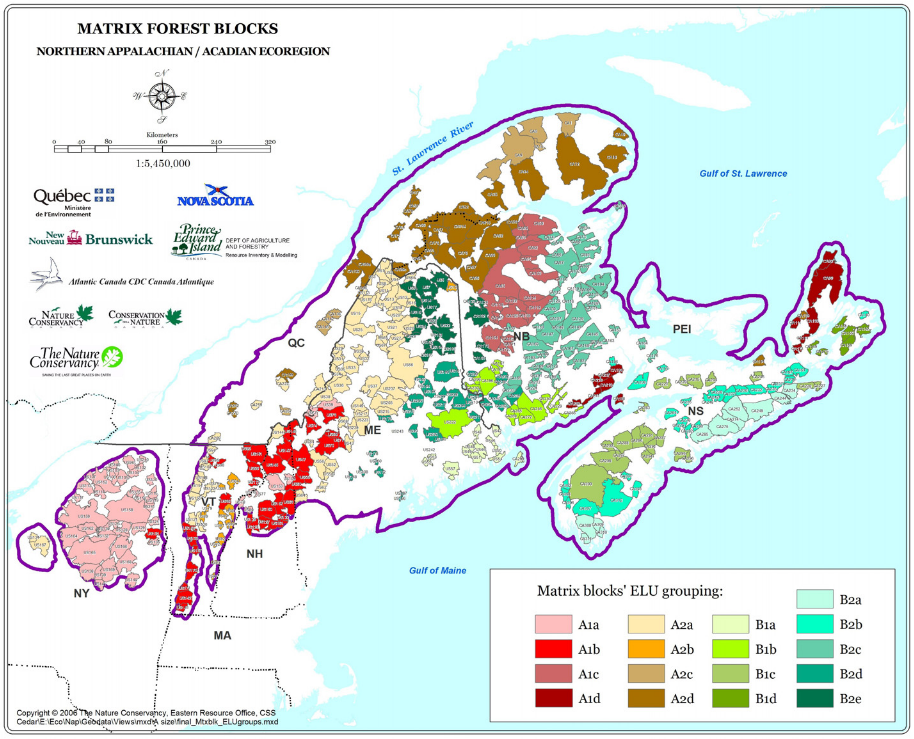


Figure 3. Matrix Forest Blocks of the Region by Type



[i]Two Countries, One Forest (2C1Forest), 6151 Allan Street Halifax, Nova Scotia B3L 1G7 Canada Phone: (902) 422-2005 James Sullivan, Executive Director james.sullivan@2c1forest.org
[ii] Anderson, M.G. et al 2006. The Northern Appalachian/Acadian Ecoregion: Ecoregional Assessment, Conservation Status and Resource CD. The Nature Conservancy, Eastern Conservation Science and The Nature Conservancy of Canada: Atlantic and Quebec Regions.
[iii]Stein, Susan et al. Forests on the Edge: Housing development on America's private forests GTR PNW-GTR-636 May 2005 p7.
[iv]For detailed information on Hubbard Brook findings visit: http://www.hubbardbrook.org/education/SubjectPages/AcidRainPage.htm
[v]Neil Rolde, *The Baxters of Maine* Tilbury House, Gardner, Maine 1997 p222

Does the canadian forest sector have a viable future?
Is current forest management acceptable to the general public?
Would you advise your kids to take forestry?

David A. MacLean

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There are some major changes occurring in the forest sector, which make it timely to take a look at the future of the sector. Canada's forest industry has faced a number of competitiveness challenges over the past few years -- almost a 'perfect storm' combination of:

1) increasing competition from lower cost producers from other parts of the world;
2) high Canadian dollar, which, according to the Forest Products Association of Canada (FPAC), results in a $528 million decline in revenue for Canadian forest companies for every cent our dollar gains against the US dollar;
3) high energy and fuel costs (e.g., Ontario electricity cost increases of up to 30% in the last year); and
4) wood shortages in the east (New Brunswick and Newfoundland) and Quebec dropping it's annual allowable cut by 20% over 3 years, following the Coulombe Commission recommendations.

The net result has been lots of bad news for the sector. Natural Resources Canada (NRCan; 2006) listed 46 specific mill closures from April 2005 to March 2006. Mill closures occurred in all regions of the country, with the majority taking place in Ontario and Quebec. Conversely, companies have also invested in operations across Canada, with the majority occurring in the west. NRCan (2006) reported over $1.8 billion of capital investment in 26 specific mills across Canada, for a variety of products including specialty papers, pulp, lumber, oriented strand board (OSB), and electricity. The softwood lumber dispute with the US has been much in the news, as have mill closures and other negative news.

In addition, there have been recent, major, high profile inquiries into forest management in Quebec (the Coulombe Commission), New Brunswick (Legislative Select Committee on Wood Supply and the resulting Task Force on Wood Supply), and other regions.

Finally, enrollment in forestry programs at universities and technical schools across Canada and internationally has been plummeting since the late 1990s, to the point that the future of several schools and the independent status of several forestry faculties is in question.

Hence, my three questions in the title. What in the world is going on with forestry, anyway? This will be a fairly high-level overview, without a great amount of detail.

1. Does the canadian forest sector have a viable future?

It is noteworthy that the feature topic of '*The State of Canada's Forests 2005-2006*' is Forest Industry Competitiveness. This provides an excellent overview of the issues and statistics related to current status and future prospects of the sector, as well as the opinions of several leaders. In short, changes in timber supply, technology, exchange rates, input costs, and world markets are forcing the industry to examine how it operates, what it produces, and where it stands in the marketplace (NRCan 2006). Costs are rising, demand is shifting or declining in some cases, competition in some areas is increasing, and raw material supply is declining in some regions. Box 1 provides an overview of some of the factors that are forcing change.

Changes in fibre supply vary regionally, from the government-imposed 20% reduction in AAC in Quebec; to mountain pine beetle-caused short-term huge salvage timber supply (450 million cubic meters killed over 8.7 million ha to date) but forecast future shortages; to mills in New Brunswick and Newfoundland reporting wood shortages. With a total of 80% of the pine in BC forecast to be affected by mountain pine beetle by 2013, there are serious concerns about future timber supply.

Box 1. What is driving change in the Canadian forest sector? (from NRCan 2006)

Domestic Forces

- Changes in regional fibre supply
- New technology
- Higher energy and other input costs

Market Forces

- Shifting demand for traditional commodities
- Changes in export markets
- More low-cost competitors on the global scene

Trade Forces

- Softwood lumber dispute
- Stronger Canadian dollar

Technology has enabled more efficient use of raw material and new value-added products like OSB, laminated beams, and I-joists. Yet, it has also resulted in reduced employment and altered the skill sets needed by workers in the sector, creating training and worker supply challenges. The effect of higher energy costs is evident to all of us, in terms of the higher costs to fill up a car at a gasoline station or to pay an electricity bill; the same things apply to shipping raw material and finished products, and processing use of energy.

Market forces include a fall in demand for newsprint, one of the historical mainstays of Canada's industry. As a result, several companies have made major investments in converting from newsprint production to specialty papers -- e.g. J.D. Irving, Ltd. (Irving Paper) has spent \$220 million over the last 3 years to expand and convert their Saint John, NB mill to supercalendered paper, and Catalyst Paper Corp. (Norske Canada) has converted their Powell River, BC mill from newsprint to specialty paper. In general, the pulp industry world-wide is shifting toward Asia, and Canada is facing stiff competition from low-cost producers in Russia, Asia, and South America (NRCan 2006). Such operators often harvest from fast-growing plantations; benefit from lower labor costs and newer, larger, more efficient mills; and operate under less stringent environmental regulations than in Canada.

In October 2006, Dr. Gero Becker, Vice-Dean of Forestry and Environmental Sciences at the University of Freiburg, Germany, gave a presentation at the University of New Brunswick, in which he compared pulp and paper industries in Canada with those around the world. Becker emphasized that the industry is global, and decisions are made by the large multi-national corporations like Stora-Enso and UPM-Kymmene and International Paper on a global basis -- the future will see mill consolidations, renovations and re-investments, but smaller or less efficient mills in many cases will close. Recycled paper is a major part of the raw material in population-dense areas like Europe and Asia, but paper can only be recycled three or four times before it is no longer useable. Canada's advantages include the best long fibre from softwoods in North America, proximity to major markets, and a large fibre resource (Box 2). However, competition and major shifts in production and markets are occurring. Becker concluded that Canada will remain a major player for high-quality virgin fibre and its products. "*Canada is very large and has a large fibre resource, but it will face stiff global competition*" he said.

Box 2. Some selected statistics about the forests and forest sector of Canada (NRCan 2006, FPAC 2006).

Canada's forests

- 10% of world's forest cover
- 30% of the world's boreal forest
- more than 25% of the world's temperate rainforest
- 25% of the world's wetlands
- 20% of the world's freshwater
- more than 70% of Canada's forests and other wooded land has never been harvested
- 40% has been deemed non-commercial or wilderness
- 104 million ha of Canada's forests are third-party certified

Canada's forest industry

- over 300 rural and remote communities depend on the forest industry for at least 50% of their income
- in 2005, forest industry shipments were \$80.3 billion, and contributed \$31.9 billion to Canada's trade balance
- employs 864,000 people of which 339,900 are directly employed

Canada is a forest nation. Clearly some major restructuring of the sector is currently going on, and there will be winners and losers. More mills will close and global restructuring will continue. But Canada does have advantages, foremost its huge resource endowment. As noted by Brian Emmett, former Assistant Deputy Minister of the Canadian Forest Service, "*Forestry is not just about forests; it is also about people and technology because it is people who transform the resource into value. This is where we must look for Canada's competitive advantage as aggressive competitors vie for our markets*" (NRCan 2006).

The northeastern US forest sector has also has seen similar restructuring and changes. In Maine, land ownership has changed dramatically since the late 1990s, with all but one large industrial ownership now dissociated from manufacturing plants and converted to instruments of short-term investment (typically 10 years) (MacLean et al. 2007). Most large private ownerships in Maine are now managed by timber investment and management companies (TIMOs) and real estate investment trusts (REITs), who have largely halted planting and precommercial thinning programs, or are held in large family estates. In discussing progress toward TRIAD forest management (a zoning approach, which involves designating forest reserves and intensively managed areas within a landscape matrix managed by silvicultural systems derived from principles of ecological forestry -- Seymour and Hunter 1999), MacLean et al. (2007) noted that the progressive initiatives of Champion International in the mid-1990s of moving toward a TRIAD management approach are now a distant memory; the corporation was acquired by International Paper in 2000, which has since sold all their lands to a TIMO and halted all investments in silviculture.

So, to answer my first question, yes, I believe that the Canadian forest sector does have a viable future. However, there will be changes, and the sector will probably look quite different in 20 years than at present. We collectively need to focus on advantages and determine how best to use the resource that we have. This formed the impetus for CFS to transfer about 20% of its research resources into a new national Fibre Centre, and to conduct restructuring and amalgamation of the Pulp and Paper Research Institute of Canada, Forintek, and the Forest Engineering Research Institute of Canada. Products, uses of the resource, and in some cases, policies need a serious reexamination and some innovative new directions are needed. There is a rapidly increasing interest in biomass for energy, biofuels, and a total biorefinery concept where biomass is used to produce a wide variety of products. Nontimber resources are also increasing in importance. Forty-six percent of Canada's land mass is made up of forests (310 million ha) and other wooded land (92 million ha). We collectively need to find ways for this to continue to contribute to the country's economic engine, or else the $80.3 billion of forest industry shipments, and $31.9 billion contribution to Canada's trade balance are at risk.

2. Is current forest management acceptable to the general public?

For this section, I'll give my answer first, and then elaborate. No, I don't think it is acceptable to most people. This is as much due to discrepancies between perceptions and reality as it is to actual unacceptable forest management practices, but the net result is the same.

Many jurisdictions have seen major public consultation and input processes into forest management in recent years -- the 1990s Ontario Lands for Life consultation and resulting Living Legacy Land Use Strategy and Ontario Forest Accord; the New Brunswick 2003-2004 Legislative Assembly Select Committee on Wood Supply; and the Quebec Coulombe Commission. I'll give a brief description of each.

Ontario - The Living Legacy Land Use Strategy aimed to establish 378 new protected areas, the biggest expansion of provincial parks and conservation reserves in Ontario's history. The Ontario Forest Accord Advisory Board (OFAAB; 2002) reported on several other resulting initiatives:

1) agreement on a proposed 'Room to Grow' policy framework that sets out how permanent increases in wood supplies will be shared between new parks and protected areas to complete ecological representation, and more wood for the forest industry to support jobs and growth;
2) confirmation that mitigation measures introduced since the Accord was signed have offset overall, province-wide reductions in wood supply for industry caused by withdrawals from logging to create new parks and protected areas through Ontario's Living Legacy in March, 1999;

3) continuing progress on regulation of the Living Legacy parks and conservation reserves; 129 regulated by the end of March 2002, with another 37 scheduled for regulation early in 2003, for a total of 166;
4) agreement on proposed methods for identifying and assessing new candidate sites for completing the system of ecological representation in the Living Legacy planning area;
5) public review of a discussion paper on Enhanced Forest Productivity, developed for the Provincial Forest Policy Committee, which includes proposals for implementation of intensive forest management (IFM) activities and use of pilot projects to test and refine IFM practices; and,
6) ongoing effort on several other Articles of the Accord, including consolidation and streamlining of the forest management guidelines by the Ministry of Natural Resources and the Northern Boreal Initiative in the far north (roughly above the 51st parallel). OFAAB recommended public consultations on this report, with particular emphasis on the proposed Room to Grow policy framework, process for identifying new candidate sites, and enhanced forest productivity measures.

This gives a flavor for the types of things resulting from the Ontario public consultation: more protected areas, maintain wood supply, more intensive management, new land-use policies.

New Brunswick - In late 2001, the New Brunswick Forest Products Association (NBFPA) submitted a letter to the New Brunswick Minister of Natural Resources requesting (a) an immediate increase in the harvest from Crown land, (b) intensification of management to enable a doubling of harvest in the future, and (c) revision of non-timber forest management goals to enable these harvest increases (Erdle and MacLean 2005). This was triggered by concerns within industry about the security of future wood supply and industrial competitiveness, stemming from: (a) the unreliability of the 10% of the industrial softwood requirement imported from neighboring jurisdictions; (b) potential wood supply shortfalls from the woodlot land base, given recent overharvesting in some parts of the province; and (c) the decline since 1992 of softwood harvest from Crown land, as a result of increased management emphasis on non-timber values.

The NB government did not act on these demands, but did agree to jointly fund, with industry, a third-party examination of New Brunswick's forest management policies and practices (Jaakko Pöyry Consulting 2002), which brought forward six recommendations:

1) A timber supply objective should be set for each Crown License area, which would be binding on both the Government and the Licensee. Timber supply objectives should be set for the range of species harvested commercially for each License.
2) The industry and NB Department of Natural Resources (NBDNR) should jointly fund and support research and development of science-based forest management practices.
3) The public should participate in reviewing the objectives of management for NB Crown lands, to provide a mandate for the direction and magnitude of change in forest management.
4) NBDNR should reduce overlap in management and oversight of Crown lands.
5) Special management zones should be critically reviewed and, where possible, additional harvesting permitted.
6) Conservation values of private lands should be taken into account when evaluating the need for set-asides and special management on public lands

Recommendations 1, 4, and 5 provoked a strong negative reaction from many interested parties outside industry circles, but by far the most controversial element of the report (Erdle and MacLean 2005) was a management scenario analyzed in the report, which suggested that intensified management and expanded plantation establishment could increase growth and thereby achieve a doubling of future harvest, while still "meeting all other environmental and social objectives for Crown Land usage". As a result, the debate about forestry in New Brunswick was elevated to such a level, with expressed opinions so strong and diverse, that in the summer of 2003 the government established an all-party Legislative Assembly Select Committee on Wood Supply, with the mandate to examine "opportunities and strategies arising from the Jaakko Pöyry report to increase available wood supply from Crown Land in New Brunswick" and to examine "opportunities and strategies for the future direction of Crown forest management".

The Legislative Select Committee held 13 public hearings, and received some 200 oral briefs and over 250 submitted letters and written briefs. The public hearings were marked by deeply-felt concerns and convictions about New Brunswick forests and their connections to the provincial society and economy. The resulting report (Legislative Assembly of New Brunswick Select Committee on Wood Supply 2004) contained 25 recommendations, which can be summarized in four categories (Erdle and MacLean 2005):

1) ***Governance and Accountability***: Several recommendations were made to greatly strengthen the connection between the public and its forest: increased public involvement in objective setting, more meaningful and complete reporting to the public of the forest status and management performance, better provision of objective information about forest management, and establishment of a Provincial Forest Advisory Committee to advise the Minister of Natural Resources on matters related to forest policy.
2) ***Forest Management Objectives***: The Committee recommended formulating timber supply objectives that reflect and maintain the natural diversity and character of the Acadian forest. This includes quantifiable wood supply objectives for all commercial tree species, and a call for reduced use of clearcut harvesting; further, it implies quantification of the character of the Acadian forest.
3) ***Allocation of the Resource and Distribution of Benefits***: To more equitably allocate benefits from the public forest across society, recommendations included allocation of harvest opportunities to small, independent local contractors, allocation of harvest volume to new value-added enterprises, encouragement of the non-timber forest product sector, and stabilization of local employment opportunities.
4) ***Provincial Wood Supply***: To promote sustainable timber supply across all land ownerships and to treat private landowners fairly, recommendations included the establishment of a dedicated and stable silviculture fund matched to forest management objectives, continued support of negotiations between private woodlot owners and industry, and increased royalty rates to reflect the premium associated with security of wood supply from Crown forests.

The Government responded to each of the recommendations of the Legislative Select Committee report in Government of New Brunswick (2005), with a sample of responses as follows:

- First Nations peoples' traditional connection to the land will be respected.
- No additional harvesting will be allowed in special management areas.

- Quality stands of hardwood, red spruce, white pine and cedar will not be clearcut.
- The public will have a greater say in how its forest is managed.
- A public participation process will be implemented.
- A Crown Forest Advisory Committee will be established with First Nations representation and major stakeholders invited to participate.
- The Natural Resources Minister will present annual State of the Forest reports to the Legislature.
- The unique characteristics of the Acadian Forest will be respected and conserved.
- Working with First Nations and stakeholders, specific strategies and actions will be developed to support economic opportunities and to sustain our natural resources.
- Government will adopt a strategy that balances the environmental, social and economic values that are important to New Brunswickers.
- A new value-added strategy will be developed.
- Long-term silviculture funding will be secured.
- Future royalty rate increases will be dedicated to silviculture.
- Current wood supply will be maintained in the short-term and increased over time.
- Companies owning land and benefiting from public land silviculture will be expected to carry out silviculture activities on their land.

Quebec - The Commission for the study of public forest management in Québec (chaired by Guy Coulombe, and hence often termed the 'Coulombe Commission') began in January 2004, with the mandate to examine the public forest management system in Québec and propose ways to improve it. Public hearings were held in 15 cities and in three First Nation communities across Québec, along with special consultations with Native communities and influential leaders regarding the future of Québec's forest sector. The Commission work included 39 days of public hearings, some 1800 consultation participants, a dozen regional discussion forums, and 303 briefs submitted. The Commission was composed of eight members (chair, commissioners and general secretary) and was assisted by professional, administrative and support staff.

The five main priorities recommended by the Commission for the study of public forest management in Québec (Coulombe Commission 2004) were meant to:

1) move away from management based primarily on wood production and consider forests as a whole, by focusing on ecosystem-based management and completion of a protected area network;
2) go from volume-based wood allocations to allocations that take into account tree quality and accessibility of forest stands in given areas;
3) move from broad-based silviculture where yields are often uncertain, to better planned silvicultural treatments that would not only make it possible to produce wood the right way, but also in the right place and at the right time, in softwood, hardwood and mixed stands;
4) prepare for the inevitable consolidation of the wood processing industry; and
5) decentralize forest management in a way that is transparent and where stakeholders are both informed and called upon to participate.

The Commission concluded that, globally, Québec's forests were being over-harvested. Hardwood forests were high-graded to remove the best trees; with only partial movement toward selection cutting, the Commission recommended that a major program be implemented to restore the quality of degraded hardwood forests. The Commission also concluded that there was a worrisome decline in softwood capital between the last two forest inventories, with the combined removal of wood from harvesting and losses from natural disturbances (especially spruce budworm outbreaks) or tree mortality exceeding the production capacity of softwood forests.

The Commission identified serious deficiencies in the methods used to assess the state of forests and to evaluate the maximum sustainable yield in a particular area, and made specific recommendations to take corrective action that should be integrated into the next management plans to be produced for each forest management unit across Québec. It also recommended caution regarding volumes available for harvest in public forests, that the government postpone the implementation of the next forest management plans for one year, in all regions (i.e., to 2008 instead of the planned 2007), and that until the new 2008 plans the maximum sustainable yield for commercial species of the FSPL group (fir, spruce, jack pine and larch) be reduced by 20% from the AAC presently in effect in each of the public forest's territorial units. For these softwood species, this interim adjustment should result in an average reduction of roughly 15% in allocations and 10% in harvest volumes, throughout Québec. For other species, the Commission recommended that maximum sustainable yields remain the same as those currently in force.

In the area of funding management activities, the Commission proposed globally readjusting the budgets currently earmarked for silviculture credits and programs aimed at protecting and developing forests. The recommendations included programs relating to six main themes:

1) acquiring forest-related knowledge,
2) building forest roads,
3) restoring the quality of hardwood forests,
4) carrying out intensive silviculture projects,
5) developing inhabited forest projects, and
6) supporting local forest stakeholders.

The Commission also recommended that the government promptly set up an implementation committee and appoint a "Chief Forester." It proposed several measures aimed at increasing the powers of regional decision makers, especially those of the Conférences régionales des élus (CRÉs), and set a timetable for the main steps towards achieving the objective, throughout Québec, of having the next forest management plans launched in 2008 according to the new management and land-use orientations.

Similarities - Results of the Ontario, New Brunswick and Quebec forest management hearings were similar in many ways. In each case, the public and stakeholders reacted very strongly to issues and concerns about how well the public forest was being managed. This resulted in sweeping recommendations to increase accountability and transparency, set aside protected areas in Ontario, change forest management regimes in at least some forest types, and better ensure maintenance of ecosystem functions and sustainability. Clearly the public is not saying that everything is OK, continue as planned. Expectations regarding public input into setting the goals for public land management have been raised to a new level in each jurisdiction.

Another similarity is the seeming rise of a ‘zoned forest’ paradigm in many jurisdictions. One version of this was proposed as the TRIAD concept of intensive management and reserve areas, within a ‘matrix’ of ecologically properly managed forest (Seymour and Hunter 1999). Each of Ontario, Quebec, and New Brunswick have increased protected areas and have evaluated, or are evaluating, increased intensive management on a portion of the landbase. I recently completed a book chapter (MacLean et al. 2007) on TRIAD as a strategy to allocate conservation efforts across managed forest landscapes, in conjunction with Bob Seymour (who coined the TRIAD term -- Seymour and Hunter 1999), Christian Messier (who is leading a major TRIAD implementation evaluation on a one million ha landbase in Quebec), and Mike Montigny (who conducted a TRIAD evaluation for an intensively managed forest in NB -- Montigny and MacLean 2006). We concluded that TRIAD or other zoning approaches (with perhaps more than three specific types of zones), offer at least two major advantages to conservation of managed forest landscapes: 1) increased area of protected areas without reduced production; and 2) better ecosystem-based management of what will undoubtedly be the largest forest zone, the ‘matrix’ forest within which protected areas and intensively managed areas are located (MacLean et al. 2007). Nearly everyone agrees with two-thirds of the TRIAD, but not with the same two-thirds. Linking intensively managed and protected forest areas together, toward meeting agreed-upon forest production and conservation goals, seems to be a viable way forward of making forest management more acceptable to the general public.

3. Would you advise your kids to take forestry?

At first glance, my third question seems to take us off on another topic, but I think it is related, and indeed closely linked to the first two.

Enrollment in post-secondary forestry programs at technical/technologist and university levels has been in dramatic decline for several years (Interim National Recruitment Strategy Steering Committee 2006). This trend has been linked to such perception factors as a negative industry image, mischaracterization of the sector as embracing of low technology, and lack of diversity both in human resources and job description (Hoberg et al. 2003). In addition, a great majority of students who go on for advanced education now come from urban and suburban areas, meaning that few matriculating students arrive at forestry schools with a practical understanding of forestry. The public perception stands in stark and disturbing contrast to predictions of an impending shortage of technical and professional workers in the forest sector (Vancouver Sun 2003).

Since the mid 1990s, there has been a national trend toward declining enrollments in forestry programs involving students continuing from high school, and decreasing financial support through job re-training programs as incentive for mature students (Interim National Recruitment Strategy Steering Committee 2006). According to 2006 statistics from the Association of University Forestry Schools of Canada (AUFSC), the eight forestry schools in Canada had a total of 3031 forestry students enrolled in the peak year of 1998-99. Total enrollment across all schools has declined every year since, by a total of 49% to 1557 in 2006, with declines in individual university forestry programs ranging from 27-72%. Forestry and other natural resource management programs have endured cyclical enrollment over the last few decades, but not to the same extent currently experienced. A number of things have changed. At the post-secondary institutions, it is an era of greater fiscal restraint and current funding models typically link program funding to short-term (declining) enrollment figures, all the while academic inflation increases costs of delivering forestry programs by about 4% per year. In the late 1990s, institutions began to develop more comprehensive recruitment strategies and make the first attempts at a new type of recruitment.

Why is enrollment so low and where are students enrolling if not to forestry programs? Six common trends have been noted (Interim National Recruitment Strategy Steering Committee 2006):

1. populations generally, and of students attending post-secondary programs, are declining, giving a smaller pool of candidates;
2. more sedentary, less outdoor-oriented students, coming mainly from urban and suburban areas;
3. poor perception of the forest sector: painted as ‘bad’ by environmentalists and lack of effective response to incorporate public environmental concerns in the curriculum, bad news stories (mill closures, trade disputes, etc), perception of a sunset, low-tech industry;
4. perception (and perhaps short-term reality) of poor employment prospects for graduates;
5. traditional students were being captured by a multitude of new “environmental sciences” programs; and
6. competitor professions were more experienced and aggressive, using a more high-tech, more attractive message and message delivery, and better use of technologies.

In many cases, the poor perception by potential students and the subsequently lowered enrollments has led to a negative feedback cycle (Box 3).

Box 3. Typical negative feedback cycle of lowered enrollment (Interim National Recruitment Strategy Steering Committee 2006).

decreasing enrollments
↓
decreasing quality and number of graduates
↓
increased cost per student to deliver program
↓
program cost reductions to decrease cost per student or
program reductions (thus reducing ability to counter the problem)
↓
threats of programs closure and/or merging with other programs
and or staff layoffs
↓
actual program closure or reduction in course offerings
↓
less attractive and relevant programs

Governments and industry are now beginning to see the effects that weaker programs with low enrollment have on abilities to meet their own mandates. In 2003, the Canadian Council of Forest Ministers undertook an employer demand survey to assess the current and future employer demand for university forester and college forest technician graduates (CCFM 2004). The survey found that employers predicted a 3% increase nationally in the number of foresters employed from 2004-2009, and that declining production of foresters was seen as increasingly important beyond 2008, with demographics suggesting that there will be an increased demand resulting from retirements from 2008-2014. These results, combined with an aging demographic, early retirement, and an older forester demographic in management positions, suggested the need to produce close to 300 forestry university graduates nationally per year during the years of highest retirement. CCFM (2004) concluded that, as it takes 4 years to graduate a potential recruit, it is important that action be taken to reverse the continuing declining enrollment trend. Without a supply of qualified foresters, the sustainability of Canada's forests may be put in jeopardy. Also along these lines, the B.C. Ministry of Forests predicted having to replace 80% of the technical/professional workforce within 10 years, and the Alberta Forest Products Association reported that the average age of forest practitioners in Alberta was 48 years.

Luckert (2004) analyzed Canadian forestry school enrollments from 1995-2003, in relation to employment trends, and results suggested that forestry-related job availability may play a large role in influencing enrollments in forestry schools, both regionally and across Canada as a whole. While correlation is not necessarily causation, the logic behind potential links between forestry jobs and enrollments, and the strength and robustness of the statistical results, suggest that causation could be important (Luckert 2004). Results indicated that there was a lag of 3 years between forestry jobs and forestry enrollments.

I'll end with some personal observations, as Dean of one of Canada's forestry schools. Would I advise my kids to take forestry? Yes, if that was what they were interested in, but first I'd advised anyone to pursue their own interests, regardless of apparent job prospects, and to be outstanding at it! Nevertheless, I believe that prospects are excellent for students now enrolled in, or coming into, our forestry program. The job situation has been strong the last several years, for good graduates who are willing to travel; clearly jobs are not abundant in Fredericton or even in New Brunswick, but there are some each year. Many UNB forestry grads are working right across Canada, in Atlantic Canada, Ontario, the Prairie Provinces, and BC.

I think that the Luckert (2004) analysis has merit, that forestry jobs are to enrollment as prey are to predators, and that the system "overshoots" with excess capacity (graduates) some times, resulting in negative feedback and correction. However, I also believe that the system has and is fundamentally changing, in relation to my first two topics -- negative public perceptions about the sector, industry restructuring and big challenges, too much bad news, etc. This is causing much wider concern than just within forestry schools now, as governments, industry, and forestry associations realize that the pool of future employees is much smaller than in the past. Plus, a great many of the 1557 students currently enrolled in the eight forestry schools are not in Registered Professional Forester-accredited programs, and have little interest in working in forest management for industry, but instead have a conservation or ENGO focus. Several initiatives are underway, nationally and regionally, to more effectively 'market' the forest sector, employment prospects, and the image of forestry as a vibrant, diverse, high-tech profession (e.g., Interim

National Recruitment Strategy Steering Committee 2006). Canada is a forest nation, and our forests provide so many important timber and non-timber values. I think that we all have a role and duty to better convey this, and the ways that forestry and forest management are improving, to the public.

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Looking at the future, forest and socioeconomic development in Quebec

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Another episode of the Canada-US trade war on softwood lumber just ends while Quebec forest industry faces a major challenge of reconfiguration. Knowing the basics of this trade war sheds light on the problems experienced by the industry north of the border. But, that is not enough to identify adequate solutions to these problems. Globalization is at work here. It is rather doom and gloom as the 10 000 people fired in the last year can tell vividly. What does it mean for a mature industry, such the forest industry in Quebec? It deserves a deep look. Also, understanding the parameters and the trends of the US markets for forest products is very telling for the future of this primary industry made of 300 lumber mills and 60 pulp and paper facilities which are very important for rural communities and the general economy of Quebec.

Does this situation of mill closure and socioeconomic degradation unavoidable? Up to now, the partnership between the forest industry and the Quebec government has worked rather well. But, it does not seem appropriate anymore. We will try to explore the avenue for change by defining the need for a patient capitalization strategy the forest requires. We will insist on the necessary industry's commitment for continuous technological modernization and product innovation. Finally, a renewed partnership between enterprises, labour unions and governments, to map the way out of the present crisis and to implement a new development strategy from the forest, will be examined. Quebec is a forested region that has to make part of its living from it. But beyond that normative statement, there is a long way to go to make it real in a near future. It is our intent to flesh out some ideas to stimulate a common understanding of a tricky problem and to poke of productive debate on how forests should be inhabited.

Abstracts from oral presentations

Note: the popular abstracts were not peer reviewed.

Sawmill wood procurement in the Northeast: Links to forest ownership

Anderson, Nate[1], René Germain[2] and Eddie Bevilacqua[2]

Parcelization of non-industrial private forestland (NIPF), or the division of single forest ownerships into multiple ownerships of smaller size, has the potential to negatively impact the profitability of the forest products industry in the Northeast by reducing economies of scale for forest management and wood procurement operations. Such impacts may be especially significant for Northeastern sawmills, which rely on local woodsheds dominated by NIPF for the majority of their roundwood requirements. Using mail surveys coupled with GIS-based geospatial analysis, this research evaluates the impact of forestland ownership patterns on the ability of sawmills to compete for stumpage and procure logs in the Northern Forest region of the Northeast. Survey responses from hundreds of mill managers and procurement professionals throughout the Northeast, including seven states and three provinces, are used to characterize wood procurement operations with regard to location and area of woodshed, sources of roundwood, average volume of stumpage purchases, trucking distances, and inter-mill competition, as well as perceptions about regional changes in log quality, log volume and other aspects of procurement. GIS analysis is used to characterize the ownership and extent of parcelization within each woodshed and evaluate variation in procurement operations linked to ownership patterns.

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Theme: Forest management, operations and engineering

Ecology of virgin balsam fir forests of Anticosti Island: A regime shift toward white spruce parklands?

Barrette, Martin[1], Louis Bélanger[2] and Louis De Grandpré[3]

The inhibition of balsam fir (*Abies balsamea*) recruitment from selective browsing by deer (*Odocoileus virginianus*) on Anticosti Island (QC, Canada) is resulting in the gradual eradication of virgin balsam fir stands. However, even in the face of this possible extinction we know little about the ecology of these balsam fir forests. This project aims to set up the basis of an ecosystem management approach to restore the ecological integrity of the balsam fir forests of Anticosti. A dendrochronological and historical approach showed us that the pristine forest landscape was predominated by old stands and that the occurrence of insect epidemics about every 20 years produced a coarse landscape mosaic with a pronounced inverse-j size distribution of disturbances. Since natural mortality processes of balsam fir are not compensated by the recruitment of young fir stems, pristine balsam fir forests show an unnatural and gradual dieback which will presumably result in a shift toward a new unnatural type of ecosystem, inland white spruce stands. However, the low abundance of white spruce regeneration in the mature white spruce stands indicates that this new ecosystem may not necessarily constitute a stable state and the harvesting of these stands might induce a second shift toward parklands.

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Theme: Forest ecosystems

Growth and quality 15 years after precommercial thinning in a tolerant hardwood stand in New Brunswick, Canada

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Short abstract

In 1988, an experiment was installed in a tolerant hardwood stand that had been clear cut in 1975. The randomized complete block design was composed of 6 replications of 4 average spacings of 2.8, 2.5, 2.3 and 2.1 m. Dendrometric measurements were taken every 5 years. In 2005, stem quality variables were also measured and three control plots were included. The 2.1 m spacing seemed the most acceptable in order to obtain higher growth and best quality products of yellow birch (*Betula alleghaniensis*), the dominant species. Regressions showed a gradual decrease in frequency of high-quality bottom 5 m logs as diameter increased, showing no optimal treatment. However, 2.1 and 2.3 m spacings provide a sufficient number of crop trees for the next commercial thinning. Sugar maple (*Acer saccharum*) did not improve its growth after thinning and had its quality reduced. Control plots show a high proportion of aspen.
Key Words : crop tree release, stand tending, yellow birch, sugar maple, silviculture

Introduction

Hardwood forests represent 35% of forested areas of New Brunswick (Can. For. Serv. 2005). NB is the third producer of hardwoods in Canada with 3.8 millions m^3 in 2003, 48% of which were harvested on crown land (MNRNB 2003). 30 hardwood sawmills are in operation in NB together with more than 275 added-value companies (Leclerc 2003).

According to a survey of NB permanent sample plots, only 5% of standing volume was of veneer or sawlog quality in 1999 (MNRNB 1999). Moreover, in 2003, less than 10% of harvested volumes were of veneer or sawlog quality in NB *vs* 30% in Québec (Leclerc 2003).

This situation arises from poor management in the past, just like diameter-limit cutting and high-grading observed elsewhere (Huot 2001, Lees 1995, Robitaille 1981). Silvicultural practices that could improve wood quality like pruning, crop tree release, thinning, etc. are seldom used in NB where they benefit from little financial incentives.

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The practice of thinning in hardwood stands is subject to divergence of opinions about optimal age, residual density, method, etc. (Strong 2000, Miller 2000, Zarnicovan 1998, Lamson et Smith 1987, Erdmann 1981). Very few thinning experiment in hardwoods were established in NB. The experiment described in the present study is one of the two that we are aware of.

The objectives of the present study are 1) to search for a residual density after precommercial thinning hardwood stands that is liable to provide a compromise between growth and quality at the stand scale, 2) evaluate which species will respond best to thinning and 3) evaluate the pruning needs after precommercial thinning.

Material and methods

The experiment is a randomized complete block design with six replicates of 4 treatments of precommercial thinning located close to the village of Napadogan, NB. It was installed by Ste Anne Nackawick pulp and paper in 1988 in a tolerant hardwood stand that was clear felled in 1975. The treatments included thinning with a brushsaw to an average residual density of A = 2 200 tiges/ha (2.1 x 2.1m), B = 1 900 tiges/ha (2.3 x 2.3m), C = 1 600 tiges/ha (2.5 x 2.5m), D =1 300 tiges/ha (2.8 x 2.8m). Three control plots were added in 2005; average density was 4 800 stems/ha (1.45 x 1.45 m) in 2005.

Measurements included: DBH, height, height to live crown base, diameter of largest branch, number of main or epicormic branches, dead or alive on the first and second 8 foot sections, number of forks, curves, social position. A relative quality classification system (modified from Sonderman 1979) was applied to each 8 foot section leading to three grades: grade 1 (veneer and sawlog), grade 2 (potential sawlog), grade 3 (potential pulplog).

Mean values for dependant growth and quality variables were compared with ANOVAs and Scheffe's multiple comparison's test at a significance level of 0.05. To combine diameter growth and frequencies of quality grading, a linear regression was used.

Results and discussion

Fifteen years after precommercial thinning in a hardwood stand, species composition was improved compared to controls by a reduction in red maple, aspen and poplars. Beech, largely affected by the beech bark disease, was however promoted (Table1).

Table 1. Species composition in percentage of density in 2005.

Species	Control	Treatments			
		2.1 m	2.3 m	2.5 m	2.8 m
Yellow birch	42.5	63.6	61.0	55.0	58.7
Sugar maple	8.3	12.2	14.8	15.9	14.6
White birch	1.7	1.6	1.6	2.2	3.4
Red maple	6.1	1.3	1.5	1.5	0.3
Beech	4.4	20.4	18.0	21.3	15.3
Aspen and poplar	37.1	1.9	3.1	4.1	7.9

Height growth was not influenced by thinning, neither was sugar maple diameter growth. Yellow birch responded more intensively by almost doubling its DBH compared to controls. There is a gradual increase in DBH as residual densities decrease (Table 2). Yellow birch diameter growth responded more than that of maple to thinning. The small response of maple was probably due to the shade tolerance of the species. Lower residual densities after thinning might have triggered a more pronounced response of maple.

Table 2. DBH of yellow birch and sugar maple in 2003. Means for the controls recorded year 17.

Species	Control	Treatments			
		2.1 m	2.3 m	2.5 m	2.8 m
Yellow birch	7,5* a	11.5 b	12.1 bc	13.0 bc	13.4 c
Sugar maple	8,5* a	8.5 a	9.0 a	10.4 a	10.2 a

Frequencies of high quality grades are much higher on the first 8-foot section than on the second one. For the first 8-foot bole, they vary significantly from the control only on the lowest residual densities for both sugar maple and yellow birch. For the second 8-foot bole, only yellow birch responds with lower frequencies of grade 1 in the thinned plots compared with controls (Figure 1). Individual stem quality variables indicated that quality decreased gradually with decreasing residual densities showing no optimum between growth and quality.

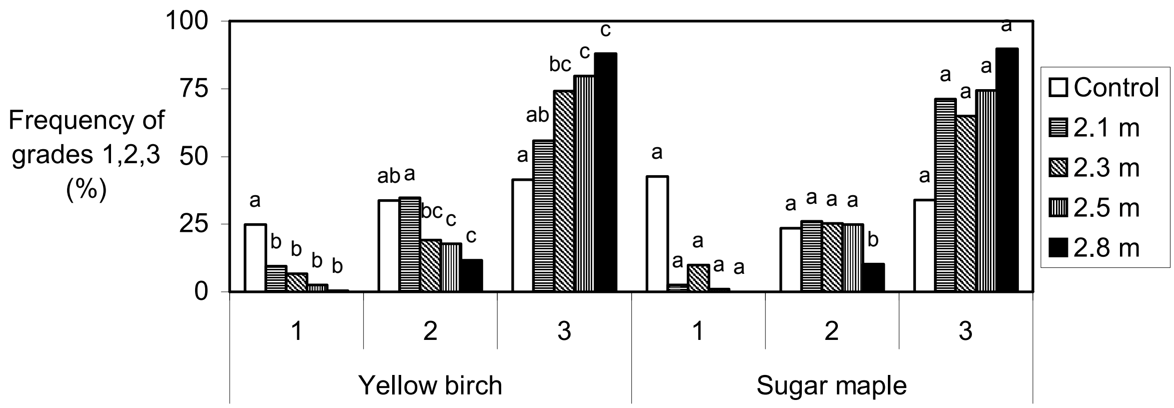

Figure 1. Stem quality on the second 8-foot section of the bole.

Spacings of 2.1 m and 2.3 m after thinning provided a sufficient number of crop trees (400 to 260 /ha) for a future commercial thinning (Figure 2). They were the most acceptable compromise between growth and quality for both species because it had the least impact on stem quality grading, because it improved tree species composition and still provided a sufficient number (400/ha) of crop trees (dominant grade 1 or 2 yellow birch or sugar maple) for future commercial thinnings. Our evaluation of the number of crop trees does not however consider their spatial distribution.

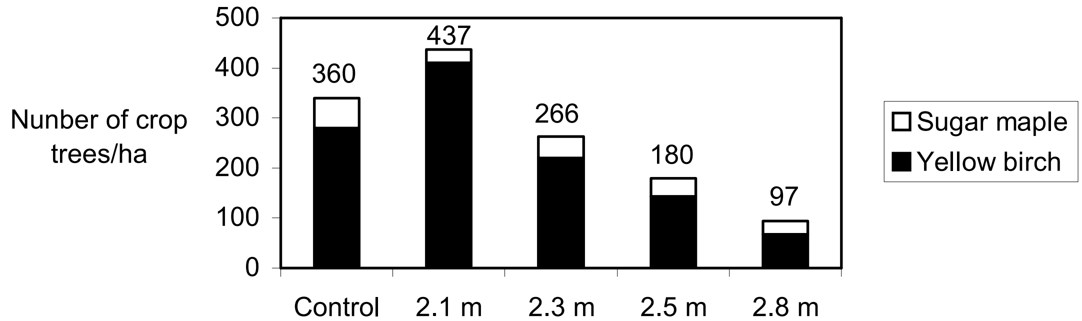

Figure 2. Number of crop trees /ha by treatment.

It is now toot late to prune the trees since branches exceed 2.5 cm thick. If pruning had been performed, the number of crop trees could probably have been increased in low residual densities.

Exploration of the variability in tree-scale response will enable to verify if the thinning had better be done with a crop tree release approach rather than an average spacing approach.

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Theme: Modeling, growth and yield

Logging patterns and landscape changes over the last century at the transition between boreal and deciduous forest zones in eastern Canada

Boucher, Yan[1], Dominique Arseneault[2] and Luc Sirois[2]

The progressive replacement of natural disturbances, such as tree fall gaps and windthrows, by logging has altered the preindustrial landscape of southeastern Québec. In this study we used maps showing the type and age of the forest cover in 1930 and 2000 within three forest landscapes of the balsam fir-yellow birch ecoregion in order to 1) describe how the spatial pattern of logging has evolved over the 20th century and 2) compare landscape structure and composition between 1930 and 2000. Results were very similar among the three landscapes. In 1930, the forest matrix was dominated by conifer stands at low elevations, whereas mixed and deciduous stands were mostly located on hilltops. In contrast, composition of the present-day forest cover shows no clear relationship to elevation. In 1930, logging activities were restricted to low elevation sites and river margins, whereas cutovers are now spread evenly across the three landscapes. Harvest practices have considerably fragmented landscapes and reduced the area of old growth coniferous stands at the expense of cut-over lands and young mixed and deciduous stands. We suggest, in accordance with the ecosystem management paradigm, that the most important properties of the preindustrial landscape should be restored to a suitable level.

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Theme: Forest ecosystems

Mapping stand site index and age with a time-series of canopy height models

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Site index (SI) is the main productivity measure in North America. For even aged and monospecific stands, it is defined as the height attained by dominant trees at a reference age. Because SI and age can only be calculated from field data, it has remained impossible to map these variables. In this study, we propose a new method to map SI and age based on a time-series of canopy height models (CHM) covering a period of 58 years. Digital surface models (DSMs) are first produced using stereo-matching applied to historical air photos. These DSMs are then normalized by subtracting the lidar ground elevations, yielding a CHM for each photo coverage. We then automatically fit existing age-height curves on a plotwise basis through the CHM time-series. To account for species variability, continuous growth was checked and a QuickBird image was used to classify conifers and deciduous trees. Results demonstrate that SI and age of conifer stands can be evaluated respectively with a low bias of 1.1 m and 2.18 years. The method can be used to produce spatially explicit maps of SI and age and to estimate productivity of remote stands for which field data are not available.

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Theme: Forest management, operations and engineering

Regeneration microsite moisture relationships following site preparation and direct seeding in southwestern Nova Scotia

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Abstract

In 2003, Bowater Mersey Paper Company Ltd. began experimenting with aerial seeding of spruce as a cost-efficient method to regenerate partially stocked harvest blocks in southwestern Nova Scotia. Factors leading to the respectively unfavourable and successful results of the 2003 and 2005 direct aerial seeding operations were examined by descriptive statistics, tree regressions, and ArcView™ image analysis techniques. Soil moisture was identified as a major environmental factor influencing survival of newly germinated seedlings on these sensitive sites. The rate of seeding was identified as a contributing factor for successful regeneration stocking of harvest blocks. A predictive tool using a slope-to-position map is described based on the relationship of soil moisture to seedling survival. Although more research is required to refine the microsite relationships of spruce regeneration with the slope-to-position map, operational recommendations for direct aerial seeding based on results to date are provided.

Key Words: slope-to-position map, soil moisture, spruce germinant

Introduction

In recent years Bowater Mersey Paper Company Ltd. has been experimenting with operational direct seeding of spruce (*Picea* sp.) in Nova Scotia, Canada as a more cost-efficient method of regenerating partially stocked and sensitive harvest blocks. Direct aerial seeding of black spruce (*Picea mariana* (Mill.) B.S.P.) is occurring more frequently in Ontario and Alberta (Fleming et al. 2001, Adams et al. 2005). Direct seeding is considered risky because of its many past failures. However, many of these failures were caused by such factors as inappropriate site selection, inadequate site preparation, and poor seed distribution (Adams et al. 2005). The biological requirements of direct seeding are more meticulous than those for planting, because both successful germination and establishment are needed (Adams et al. 2005). The factors leading to

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the respectively unfavorable and successful results of the 2003 and 2005 direct aerial seeding operations were examined by descriptive statistics, tree regressions, and ArcView™ image analysis techniques.

BMPC's objectives were predominantly to determine the success of the direct aerial seeding operations and obtain knowledge to understand the factors the led to successful results and the reasons for regeneration failures. This study's objectives were also to examine the relations between environmental factors and the slope-to-position index, and from this information to develop a predictive management tool for assisting in future direct aerial seeding operations.

Soil moisture was identified as a major environmental factor influencing survival of newly germinated seedlings on these sensitive sites. Recent increases in annual temperatures may be a primary factor in spruce seedling mortality on these sites in Nova Scotia. The rate of seeding was identified as a contributing factor for successful regeneration stocking of harvest blocks. A predictive tool using a slope-to-position map is described based on the relationship of soil moisture to seedling survival. Although more research is required to refine the microsite relationships of spruce regeneration with the slope-to-position map (Bourque et al. 2005), operational recommendations for direct aerial seeding based on results to date will be provided.

Methods and materials

Study Sites

The study sites were located in southwestern Nova Scotia on BMPC freehold land. The direct aerial seeding operations from 2003 and 2005 have been used in this study, with data analysis concentrating on the results of the 2005 operation. Rowe (1972) classifies the study locations as occurring in the Atlantic Uplands forest section of the Acadian Forest Region. The Atlantic Uplands have historically been considered to be one of the more humid parts of Nova Scotia because of exposure to moisture-laden winds from the ocean. The close proximity to the ocean can cause local variation in temperature and precipitation.

Treatments

Black spruce, white spruce (*Picea glauca* (Moench) Voss), and red spruce (*P. rubens* Sarg.) were seeded with an aerial seeder contained in a Bell 206 JetRanger. In 2003, the seeding rates ranged between 40 000 to 50 000 seeds /ha. Except for one harvest block in 2005, the seed rate was 100 000 seeds /ha. A seeding rate of 200 000 seeds /ha was selected for the exception. Site preparation was conducted using barrels and chains.

Measurements

Between five and 15 circular 5-m^2 (r = 1.26 m) plots were established along transect lines in each harvest block. The transect line followed a moisture gradient from dry to wet conditions along hill sides. The germinants were located in each plot and identified by species and treatment (natural or direct seeded). Both germinants and advance regeneration were counted and height (cm) of the tallest individual was recorded. The microsites were classified by type, and recorded visually as percent cover by type to the nearest 5%. Also recorded for each plot were the percent cover of non-woody ground vegetation by species and of coarse woody debris, and soil drainage and texture. The surface moisture (% volume of substrate water) measurements were recorded in August 2005 at the driest part of the summer using a moisture meter.

Statistical Analysis

The relationships between the stocking and density of new germinants the various site preparation treatments, and the site variables have been examined first using graphical techniques and then linear and non-linear regression techniques of regression trees (Wilkinson 1997). Arcview™ 3.3 (ESRI 2002) was used to illustrate the spatial effects of mapped geographical features and measured data along each line transect. The slope-to-position index with a 10 m resolution was used to compare relationships between germinants and environmental variables. The index map was produced by the Nexfor /Bowater Forest Watershed Centre (http://www.unb.ca/departs/forestry/centers/centres-fs.htm) at the University of New Brunswick for the Nova Scotia Department of Natural Resources in 2005. The slope-to-position index represents the calculated distance to the high water table. The mean slope-to-position index was identified for all plots using the Image Anaylsis tool of Arcview 3.3 (ESRI 2002). A 10-m buffer was placed on the plots for analysis in order to account for variation. ArcView was also used to map the most important measured variables (surface moisture and germinant density) by line transect to visually compare trends.

Results and discussion

MicroSite Relationships

The germinant density varied across all harvest blocks. Surface moisture had the greatest effect on the density of spruce germinants (fit = 0.263). The seeding rate (100 000 seeds /ha, or 200 000 seed /ha) was the next major factor once germinant moisture requirements were satisfied (fit = 0.274). Well-drained sites that were wet and seeded at 100 000 seeds /ha had a higher germination rate than the poor, moderately well, or rapidly drained sites. The germinant stocking showed similar results to that of germinant density. The average soil moisture varied with microsite type. Seedbeds with surface moisture above 13% (2005) had the most successful rate of germination. In agreement with past studies, site preparation tended to improve the germination success rate of the direct seeding operation.

Slope-to-Position and Moisture Relationships

A negative linear relationship was observed between the depth-to-water-table index and surface moisture. The same relationship was exhibited between the slope-to-position index and the density of germinants. A parabolic relationship was obtained between percent soil moisture and density of germinants. The difference in data structure for a measured continuous variable (soil moisture) and an index variable (slope-to-position index) may have contributed to different relationships in the density of germinants. Germinant density in undistributed areas followed expected trends of germinants occurring only in plots with surface moisture over 13%. The same trend was more variable in the site-prepared areas.

Conclusions

In this study, surface moisture is the most critical factor for successful germination. Site preparation aids in surface moisture retention and obtains more germinants. Site selection is extremely important to the success of aerial seeding. Good potential sites include young cutovers (2–3 years) with low to moderate competition, moderate to high soil moisture, and moderate to heavy site preparation. The increased seeding rate in 2005 was a major factor in the observed regeneration success. A seeding rate of 100 000 viable seeds /ha should be used as the general guideline in the future. Refinement of a predictive tool based on the slope-to-position index will assist management decisions for direct seeding for enhancing ecological forest management. Direct aerial seeding will not replace manual planting, but rather complement it.

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Theme: Silviculture

Factors influencing the formation of darkwood in sugar maple: Results from log yard inventories

Coates, Adam[1], Ruth Yanai[2] and Rene Germain[2]

Sugar maple (*Acer saccharum*) is an important commercial species of the northeastern United States and southeastern Canada. It is most valued for its light-colored wood and as a result, landowners and forestry professionals involved with managing, harvesting, and selling timber would benefit from the ability to predict the formation of dark-colored wood at the heart of these trees. Regional differences in darkwood formation have been anecdotally described but not, to our knowledge, scientifically documented. To investigate this issue, we conducted inventories in sawmill log yards across the northeastern U.S. in 2005 and 2006. We measured the overall log and darkwood diameters from the small end of non-veneer butt logs and proportion of darkwood as a fraction of the total cross-sectional area. Our results indicate that this ratio does not differ significantly across the region. We also collected information regarding the source of the logs to test the effect of soil order on heart size, but found none. The next phase of research will involve examining the variation in heart size within selected sites, focusing on relationships with micro-site conditions and disturbance history.

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Theme: Forest management, operations and engineering

The limits to growth: Is productivity constrained by carbon assimilation?

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Much of the research over the past few decades into the physiology of forest productivity has focused on carbon fixation. In theory, significant increases in forest productivity could be accomplished if we maximize the efficiency by which trees capture sunlight and combine it with inputs of CO_2, water and nutrients to form simple sugars, which provide the building blocks for wood fiber and other biomass components. However, numerous studies show that fertilization with nutrients, CO_2 enrichment, and irrigation, even in combination, often provides only modest (at best) increases in productivity. These observations suggest that productivity may not be limited by assimilation, but by the genetically determined ability of trees to use carbon for growth.

Using red spruce as a model species, we investigated the relevance of source-sink relationships to age-related trends in productivity, the underlying mechanisms of which have defied experimental validation despite substantial efforts by many researchers. Productivity increases from juvenile stages, peaks during mid-age, and declines as trees age further. Source-related metrics, such as photosynthetic capacity and *in situ* rates, decreased between juvenile and mid-aged life stages while productivity increased, then remained constant between mid-aged and old stages while productivity decreased by as much as 50%. In contrast, sink strengths robustly tracked productivity. Foliar starch storage, an indicator of surplus CO_2 assimilation, was inversely related to productivity and indicated substantial excess photosynthetic capacity over growth demands in the old trees. This occurred in spite of a very large cone-crop sink on the oldest trees during the measurement year. Our results suggest that when investigating tree productivity, understanding sink demand is as important, perhaps more so, than understanding assimilatory attributes.

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Theme: Tree physiology, carbon and nutrient cycles and genetics

Leave patches as refugia for forest vascular plants in harvest blocks

de Graaf, Megan[1]

Leaf patches have been suggested as a management tool for conserving herbaceous plants that would otherwise decline after harvest. These patches may also serve as source populations for recolonizing the harvest area, though functions may be impaired by edge effects. Changes in microenvironment, due to harvesting disturbance, could extend into the patch, influencing the composition and persistence of species. Previous studies have found that these edge effects can extend between 5-15 m to 200+m beyond the edge. The main objective of this project is to characterize herbaceous-layer response to harvesting disturbance in leaf patches in the short term. Four experimental and two reference 1 ha patches were established, with transects at each aspect (compass direction), each with 5 1 m^2 quadrats at 50 m and 5 m outside the patch, 0 m (edge), and 25 m, 35 m, and 50 m (centre) inside. Variables sampled throughout patches include percent cover of ground vegetation, substrates, disturbance, slash, and canopy, as well as light, humidity, temperature, and windthrow. Preliminary results suggest that some forest species decline after disturbance, while others increase, that edge effects may not penetrate 25 m for certain variables, and that edge effects vary by aspect. By investigating species' responses to changed microenvironmental gradients, recommendations on patch size, shape, and orientation can be made.

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Theme: Forest ecosystems

Barriers leading to an insufficient regeneration in early-successional stands originating from old-fields

d'Orangeville, Loïc[1], Alain Cogliastro[2,3] and André Bouchard[2,3]

Even though the total forest area of the North American continent continues to decrease, regions of eastern North America, such as New England or the southern part of the province of Quebec, have experienced in the last century a gradual loss of agricultural lands. This major shift in human land use has released numerous sites now dominated by early-successional plant communities. Natural forest regeneration of these old-fields is said to be slow, difficult and even unpredictable. Will high-value mature forests replace these pioneer tree-dominated stands? Twenty-eight old-fields ranging from 15 to 61 years of age, all characterized by a closed canopy of pioneer tree species, were sampled for their regeneration stocking. The aim of this study was to measure whether various agro-forested landscapes, ranging from 28% to 59% of the forest cover, could assure hardwood regeneration and if not, to determine what the barriers to that regeneration are. Our results show that hardwood regeneration on former farmland now dominated by early-successional forest in southwestern Quebec is insufficient. Because of this low stocking, we narrowed the relative importance of plant competition, soil characteristics and also spatial context of old-fields in the landscape, using G.I.S. technology, for explaining the quality and abundance of tree regeneration. Using stepwise variable selection, redundancy analysis and variation partitioning, we analyze and discuss the spatial and environmental barriers to sufficient regeneration.

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Theme: Forest ecosystems

Incidental take of migratory birds and the forest industry: An opportunity for integrated adaptive management

Drolet, Bruno[1] and Hélène Lévesque[2]

Leaving the management of non-game forest birds to the forces of nature alone can no longer be justified. These birds, which form the majority of vertebrate animals in our forests, are showing obvious signs of decline. Even though these migratory bird species are not hunted, each year their population is significantly affected by a number of human activities. One of these impacts is incidental take, defined as the unintentional killing of migratory birds, and/or the disturbance or destruction of their nests or eggs resulting from legitimate human activities on the landscape. Currently, the 1994 *Migratory Bird Convention Act* (MBCA) and its associated regulations do not differentiate between the deliberate destruction of nests and incidental losses stemming from other activities. Environment Canada is considering the development of an alternative management approach based on a regulatory framework that meets Canada-US commitments towards long-term conservation of migratory bird populations, while also solving issues regarding compliance with the MBCA in the natural resources context, including commercial timber harvesting. This presentation will summarize the current situation in the forestry industry and will lay the foundation that will guide the search for a solution.

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Theme: Wildlife

Impact of dispersed cutting blocks on wood supply cost

Favreau, Jean[1]

A model was developed by FERIC to assess the additional costs associated with the level of dispersion of cutting blocks. Dispersion costs were assessed without taking into account the reasons for the dispersion such as harmonization with other users, natural disturbances, various types of cuts, legal constraints, regional history of harvesting or terrain conditions. The model includes the following cost items: harvesting, hauling, road construction and maintenance, lodging, and supervision and planning. The degree of dispersion was defined by a very simple measure and expressed as harvested volume per kilometer of dispersion. Cost equations were then derived to calculate the additional costs generated by the level of dispersion. The model was tested successfully on many public forests in Quebec.

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Theme: Forest management, operations and engineering

Distribution and dynamics of the pine marten, *Martes americana*, in an industrial forest in northwestern New Brunswick

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Anne-Marie Pelletier[2] and François Villeneuve[2]

Pine marten is usually associated with old-growth spruce-fir forests, but much recent research revealed its presence in other types of habitat, such as deciduous or second-growth forests. For 5 years now, Claude Samson et al. have studied pine martens in an industrial forest where intensive silviculture has been practiced since 1960. We found that pine martens do not use plantations <20 years but do use plantations >20 years. A preference for natural stands was detected, particularly in winter. Plantations >20 years present good abundance of preys, canopy closure and basal area for the pine marten, but poor abundance of coarse, woody debris. We evaluate overall health of the population by measuring age structure, body weight, density and mortality rate. We consider whether a landscape with a large proportion of plantations >20 years could be a good quality habitat for the pine marten.

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Theme: Wildlife

What rules the sprouting of edible forest mushrooms in Gaspé peninsula?

Gévry, Marie-France[1], Luc Sirois[2] and Mathieu Côté[3]

Most of the edible forest mushroom species are symbionts of tree species. Because forest cover varies among regions, studies aiming at understanding fungi-forest relationships are fundamental for assessing the potential of each region and ultimately for assuring a viable harvest of the resource. The objectives of this study are to establish (1) the role of forest cover and abiotic factors in determining the abundance of (pre)selected edible mushroom species and (2) their phenology, in the Gaspé Peninsula. During summer 2005 and 2006, 896 permanent quadrats were established systematically along transects in 14 forest stand types representative of Gaspé forests and were surveyed every 7 days. As the summer 2005 was quite dry, the species more frequently seen were *Boletus aff. edulis*, *Leccinum* spp., *Lactarius deterrimus*, *Catathelasma ventrisosum* and *Rozites caperata*. The greatest abundances were noted in Norway spruce (*Picea abies*) plantations that had experienced thinning (26.5% of total harvested observations), white spruce (*Picea glauca*) plantations (24.2%) and young mixed forest stands (15.79%) whereas all other natural forest stands surveyed (which cover about 95% of the Gaspé Peninsula area) had the lowest abundances. Preliminary field observations during the 2006 summer showed a greater diversity among species surveyed, which showed greater abundances in natural forest stands than in summer 2005. The influence of soil humidity and temperature induced by a very rainy season in 2006 may explain part of these observations. Results of the harvests per different forest stand type for summer 2006 and preliminary results concerning fungi-forest relationships will be presented

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Theme: Forest ecosystems

A large-scale investigation of the black spruce growth dynamics in the lichen woodlands throughout the closed-crown forest zone

Girard, François[1], Serge Payette[2] and Réjean Gagnon[3]

Boreal forests account for 55% of Canada and are divided into three different vegetation zones, 1) the closed-crown forest zone, 2) the lichen woodland zone and 3) the forest-tundra zone. The closed-crown forest zone includes a dominance of dense coniferous stands on well-drained soils. However, the overall distribution of these stands dominated by black spruce is not homogenous, with several patches of lichen woodlands. In the study area which covers 112 000 km^2 across the closed-crown forest zone, a 1 km large and 140 km long transect was laid out at each 15 minutes of latitude from 47° to 52° N to map lichen woodland distribution and cover. In each transect, the proportion of lichen woodlands was evaluated and a total of 60 sites were randomly selected across the gradient from south to north, and growth analysis was performed on a total of 10 trees in each site. Trees younger than 100 years old generally show large tree rings, whereas trees established before 1900 are markedly smaller and shorter. Growth reduction from the spruce budworm is widespread in most lichen woodlands of the study area, but the outbreaks were more damaging in the southern part of the study area.

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Theme: Forest ecosystems

Evaluation of gene flow between exotic and native *Populus* species as a tool for forest certification

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Introgression from exotic into native species could have short- and long-term impacts on the genetic diversity of indigenous species. Estimation of gene flow from plantations with exotic components to native poplar stands therefore constitutes an important step in the assessment of the ecological and genetic risks linked to the introduction of exotic species. In this study we use two different types of species-specific genetic markers to monitor the rate of gene flow from plantations of hybrid poplar with exotic components (*Populus maximowiczii, P. nigra* and *P. trichocarpa*) into natural populations of their native congeners (*P. balsamifera* and *P. deltoides*). Results obtained for three consecutive years show a high rate of hybridization, though part of this hybridization was between native species. These results provide a "snapshot" of the present situation and could be used to outline future criteria to protect the biodiversity of natural forests. The process of forest certification performed by the FSC (Forest Stewardship Council) examines the commitment of a company to responsible forest management. The careful control and active monitoring of exotic species, necessary to avoid adverse ecological impacts, is an important step in this procedure. Our study could be useful for forest certification, helping to determine the environmental impact posed by plantations with exotic components.

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Theme: Tree physiology, carbon and nutrient cycle and genetics

Truncating radial growth series for tree mortality probability estimations

Hartmann, Henrik[1], Christian Messier[2] and Marilou Beaudet[2]

Tree ring chronologies have been widely used in studies of tree mortality assuming that radial growth is indicative of tree physiological vigor. Based on recent radial growth, mortality probabilities can be estimated through several statistical tools such as logistic regression. However, individual tree mortality is a rare event and the year of death of sampled dead trees usually spans across years to decades. Comparisons of recent radial growth of live and dead trees fall in different time frames allowing external factors (e.g., climate, disturbance) to influence recent radial growth differently. Hence, the growth-vigor assumption might be influenced by climate and disturbance. To counteract this problem we propose the truncating of live growth series to synchronize live and dead recent radial growth periods.

Using different growth scenarios from several species, geographic regions, and disturbance regimes, we evaluate the impact of truncating on model development and performance using logistic regression analysis. In most applications, truncating will strengthen the discriminative ability of the model. It is concluded that truncating live growth series helps to decrease the influence of external factors on radial growth and thus enhances the growth-vigor relationship and the model's general applicability.

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Theme: Modeling, growth and yield

Nighttime ecosystem respiration modelling for balsam fir *(Abies balsamea)* forests in eastern Canada

Hassan, Quazi K.[1], Charles P-A. Bourque, F.-R. Meng, C.W. Clowater, and Z. Xing

Abstract

Quantification of nighttime ecosystem respiration (R_E) in balsam fir (*Abies balsamea;* bF*)* forests is important to understand carbon dioxide exchange from bF ecosystems. This paper provides a modeling approach to estimate R_E as a function of above-canopy air temperature (T_a). The measurements of R_E and T_a used in the research are obtained from the Nashwaak Lake flux-site (NWL) in central New Brunswick (NB), Canada. Quality of R_E measurements is regularly affected by excessive precipitation and sensor wetting, low wind velocities, and sensor malfunctioning. Problematic measurements are routinely excluded from further data reduction and analysis. Measurements within a time window from 11 pm to 4 am (i.e., local time) are selected in the calculation of nighttime R_E and associated mean T_a. We have applied three approaches to model R_E, namely (a) van't Hoff's (vH) model, (b) Q_{10} parameterization, and (c) Lloyd and Taylor's (LT) model; all are functions of temperature. These three approaches are found to have similar level of predictability (i.e., $r^2 \approx 62.5$-64.7%) with NWL data. Since bF is an important component of forests in NB, our results are broadly applicable to many of the forests across NB.

Introduction

Since the 1990's eddy-covariance techniques have been widely used in monitoring carbon dioxide (CO_2), water, and energy fluxes at half-hourly to hourly timesteps over various ecosystems around the world. As part of the Fluxnet-Canada project, several eddy-covariance (flux) towers have been operational in New Brunswick (NB) since 2003. The eddy-covariance technique acquires measurements of net ecosystem exchange (NEE; i.e., the difference between gross CO_2 uptake through photosynthesis and release of CO_2 through respiration) by monitoring rapid fluctuations in CO_2 concentrations and the vertical wind field. Their statistical treatment after co-ordinate rotation and application of various corrections provides an estimate of NEE. During the night, there is no photosynthesis; as a result, NEE measurement at night represents the nighttime release (contribution) of CO_2 from the soil, and above and belowground biomass to the atmosphere, as nighttime ecosystem respiration (R_E). Our focus in this study is to model R_E using eddy-covariance measurements of NEE collected over a balsam fir *(Abies balsamea;* bF*)* forest in west central NB.

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In modeling respiration, the most commonly used method is based on an empirical exponential relation between respiration and temperature (van't Hoff 1884; referred to the vH model in this paper). Another commonly used method is the Q_{10} parameterization, which accounts for the increase of respiration for every 10°C increment in temperature (e.g., Schmid et al. 2000, Lavinge et al. 2004). The Q_{10} parameterization is an extension of van't Hoff's model. The third method is based on Lloyd and Taylor's (LT) model (Lloyd and Taylor 1994). Despite controversy over these approaches, comparative research shows it is possible to get reasonable agreement between observed and predicted rates of respiration based on temperature (e.g., Singh and Gupta 1977, Raich and Schlesinger 1992, Lloyd and Taylor 1994). In this paper, we investigate the level of predictability offered by the three models by comparing model predictions with tower measurements of nighttime R_E collected over a bF forest in west central NB for the 2004 and 2005, May-September growing periods.

Methodology

Site Description

The measurements (i.e., NEE and above-canopy air temperature) used in this research are acquired over a 36-year old bF stand at the Nashwaak Lake site (NWL), in west central NB, Canada (centred around 46°28'20" N, 67°06'0" W). The mean height of the stand is about 12-15 m with a basal area of 26 $m^2\ ha^{-1}$ and a measured leaf area index (LAI) of 8.4 $m^2\ m^{-2}$ (Chen et al. 2006). The soil is a well-drained sandy loam, having a mean duff thickness of about 6-7 cm (Xing et al. 2005). The site has many large boulders interspersed along the surface. It is located in hilly terrain with an average elevation of 341 m above mean sea level. The site falls within the Atlantic Maritime ecozone; its climate is largely influenced with its proximity to the Atlantic Ocean. The study site experiences a cool-moist climate, where mean annual air temperature and precipitation are 2.1°C and 1196 mm, respectively.

Data Processing

Quality of R_E measurements is frequently affected by excessive precipitation, low friction and wind velocities, and sensor malfunctioning. To filter the data and to ensure representation of nighttime conditions, we use the following screening criteria:

(i) A time window from 11 pm to 4 am (i.e., local time) is used to ensure that nighttime values are selected,

(ii) NEE values under low wind speed conditions (i.e., $\leq$ 0.50 m s^{-1} and u*'s, friction velocities $\leq$ 0.25 m s^{-1}) are filtered out, as low wind speeds cause insufficient turbulent mixing and associated NEE values are generally unrepresentative (Hollinger et al. 2004),

(iii) Negative nighttime CO_2 fluxes are ignored, as these are considered problematic, and

(iv) NEE values generated during precipitation events are ignored, as sensors can produce unrealistic measurements under excessive wetting conditions.

For specific nighttime periods, after data filtering, if at least four half-hourly measurements are available, averages of R_E and T_a are calculated.

Model Description

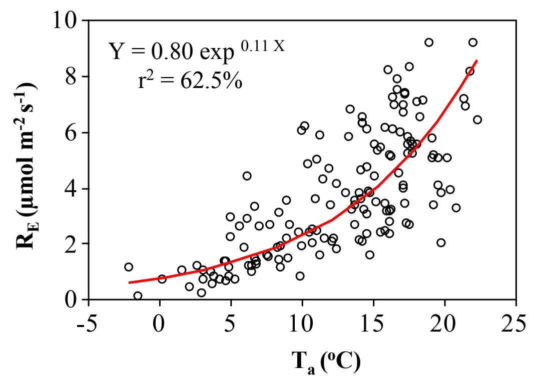

Fig.1. Relation between R_E and T_a over bf ecosystem.

Eqn. [1] is the vH model and is expressed as an exponential relationship of temperature.

[1] $$R_E = a\exp^{bT_a},$$

where R_E is in μmol m^{-2} s^{-1}, "a" and "b" are equation coefficients, and T_a is the average nighttime abovecanopy air temperature in ^oC. To obtain values for "a" and "b", we use non-linear regression to fit eqn. [1] to the data (Fig. 1). The best model fit gives us an r^2-value of 62.5% and equation coefficients of 0.80 and 0.11 for "a" and "b", respectively. The coefficient values will be used later to estimate the value of Q_{10} in eqn. [2], below.

Eqn. [2] is associated with the Q_{10} parameterization methodology described earlier. The Q_{10} coefficient in its expression,

[2] $$R_E = R_{10}Q_{10}^{\frac{T_a-10}{10}},$$

is equal to the $\exp^{bT_a}$ term in vH's model, but in this case T_a is set to 10^oC. Generally, a constant value is used for Q_{10} (≈2.0), but it has been shown to vary from place to place. We have opted to calculate Q_{10} directly from our data. Using coefficient value for "b" calculated earlier, we estimate Q_{10} to be approximately equal to 3.0. This value compares well with Q_{10}-values calculated by Lavinge et al. (2004) for bF ecosystems in other parts of NB, where mean Q_{10}-values varied from 2.5 in 1998, to 3.0 in 1999, to 2.7 in 2000 using soil temperature. The R_{10} term (μmol m^{-2} s^{-1}) in eqn. [2] is the average nighttime respiration at 10^oC.

Eqn. [3] is associated with the LT model, and the values of the coefficients are based on values provided in Lloyd and Taylor (1994), i.e.,

[3] $$R_E = R_{10}\exp^{308.56\left(\frac{1}{56.02}-\frac{1}{T_a+273.15-227.13}\right)}.$$

Results and Discussions

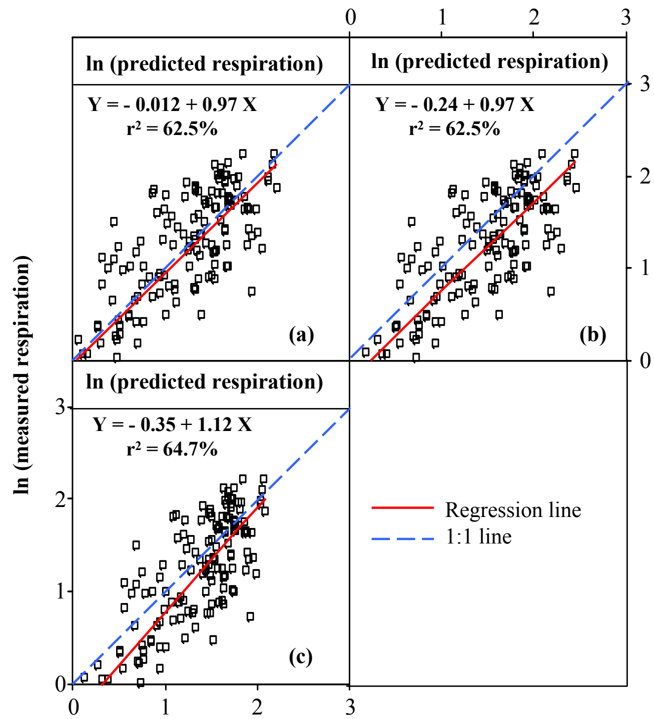

Fig.2. Comparison of R_E between predicted and measured values using (a) vH model, (b) Q_{10} parameterization, and (c) LT model.

Fig. 2 shows a comparison between predicted and measured R_E values using (a) the vH model, (b) Q_{10} parameterization, and (c) LT model for the growing seasons of 2004-05. All three approaches provide similar level of predictability (i.e., $r^2 \approx 62.5\%$ for both the vH and Q_{10} model, and $r^2 \approx 64.7\%$ for the LT model) when compared to measured values of R_E. Predictions of the vH model have the best conformity with the 1:1 line.

Conclusions

This paper has demonstrated the use of vH model, Q_{10} parameterization, and LT model; the methods give reasonable predictions of R_E (i.e., $r^2 >= 62.5\%$). As bF is one of the important species in NB (comprising about 19% of the total NB forest landscape), our model could potentially be used for modelling R_E over bF ecosystems across NB. This research is useful for understanding the significance of bF ecosystem contributions to the nighttime exchange of carbon between the ecosystem and the atmosphere.

Acknowledgements

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Theme: Modeling, growth and yield

Characterisation of regeneration and seedbeds in cedar stands of the Gaspé Peninsula

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Réjean Gagnon[2] and Sylvain Fortin[3]

Circumstances leading to successful recruitment of northern white cedar (*Thuja occidentalis* L.) are poorly understood. In order to develop ecosystem-based silvicultural methods that encourage cedar to regenerate, we characterized regeneration and seedbeds in cedar stands before and after harvesting. In order to define appropriate silvicultural strategies, the project aimed to 1) characterize the regeneration and seedbeds in mature cedar stands; 2) characterize the regeneration and seedbeds in harvested areas and 3) to measure the amount of layering regeneration occurring in natural gaps in a mature cedar stand. The two mature cedar stands studied were over 300 years old and free from any major disturbance during this period. On the other hand, 14 harvested areas (3 to 16 years since clearcut) were studied. All sites were on mineral land deposits and the drainage was good to medium. The results show that in the mature cedar stands, the cedar seedlings rarely exceed 30 cm in height and most of them tend to grow on woody debris. By comparison, the woody debris is not often colonized in harvested areas where the success of seedlings tends to depend on whether there are short mosses at the site. Moreover, the study of regeneration in the natural gaps of mature cedar stands showed that recruitment of cedar tends to depend on layerings that dominate among the highest regenerating stems. These results led us to carry out a gap harvesting trial in cedar stands in which a follow up of the regeneration will be done.

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Theme: Forest ecosystems

Optimized salvage, harvest scheduling, and protection to reduce harvest impacts during large spruce budworm outbreaks

Hennigar, Chris R.[1] and David A. MacLean[2]

Spruce **b**ud**w**orm (*Choristoneura fumiferana* Clem. (SBW)) severely defoliates balsam fir (*Abies balsamea* (L.) Mill.) and spruce (*Picea* spp.) in large periodic outbreaks. A modeling framework has been developed to integrate stand-level SBW volume impacts into an industrial-scale timber supply optimization model (Woodstock) for the 209,000 ha Black Brook District, in northwestern New Brunswick, Canada. Advantages of this integrated approach include using linear optimization to simultaneously re-optimize the harvest schedule, optimize salvage, and identify optimal areas for insecticide application. A total of 195 scenarios, including normal and severe SBW outbreaks beginning in 2002, and 24 combinations of foliage protection strategies (four foliage protection efficacies and six protection timings) were simulated. Following severe defoliation from 2008-2016, maximum harvest reductions of 39 and 53% for normal and severe outbreaks occurred in the 2012-2016 period, and these were reduced to 27 and 34% when salvage and re-optimized harvest scheduling were used. Capturing salvageable volume was the main factor that reduced defoliation impact on harvest between base (undefoliated) and defoliated (re-optimized, salvage) harvest schedules.

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Theme: Forest management, operations and engineering

Growth comparison of northern white-cedar to balsam fir and red spruce by site class

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Abstract

Though northern white-cedar is a common and economically important component of the Acadian Forest of Maine and adjacent Canada, there is little regional data about the growth and development of this species. Sixty sites in northern Maine were used to compare growth of cedar to that of red spruce and balsam fir along a range of site classes and light exposures. On average, cedar grew faster than spruce but slower than fir, however species-specific basal area growth rates were affected differently by site class and light exposure. Balsam fir was the only species showing strong growth responses to increased crown light levels. Decay was present in all species, but a higher proportion of cedar stems were decayed. The proportion of decayed balsam fir stems increased as site drainage improved. Our data suggest that cedar in Maine often exceed 150 years of readable rings at breast height.

Introduction

Northern white-cedar (*Thuja occidentalis* L.) is arguably the least-studied economically important conifer in the northeastern North America. It has important niche market value as shingles, shakes, fence posts, and mulch, and provides winter yarding habitat and browse for wildlife species such as white-tailed deer (*Odocoileus virginianus*). Northern white-cedar composes approximately 10% of the Maine forests (McWilliams et al. 2005). Recent forest inventory data suggest that cedar growth since 1995 has been approximately 15 million cords, while removals have totaled nearly 25 million cords. Due to the lack of research into cedar ecology and responses to silviculture in this region, land managers are forced to enter stands with sparse knowledge of regeneration dynamics, growth responses and stand structural characteristics that would favor cedar on a sustainable basis. As such, cedar stands are commonly exploitatively harvested.

The goal of this research is to inform the management decisions made by field foresters who desire to maintain or increase cedar as a component of mixed-species stands. The objective of the study reported here was to compare the most recent complete five years of growth of northern white-cedar to two commonly associated species, red spruce (*Picea rubens* Sarg.) and balsam fir (*Abies balsamea* L.), along a range of site classes and light exposures.

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Methods

Sixty sites throughout northern Maine were selected for this study (Figure 1). Sites were provided by many private industrial cooperators as well as the Maine Bureau of Parks and Lands, the Nature Conservancy, and the Baxter State Park Scientific Forest Management Area. This covers a wide range of landowners and associated management strategies common to the region.

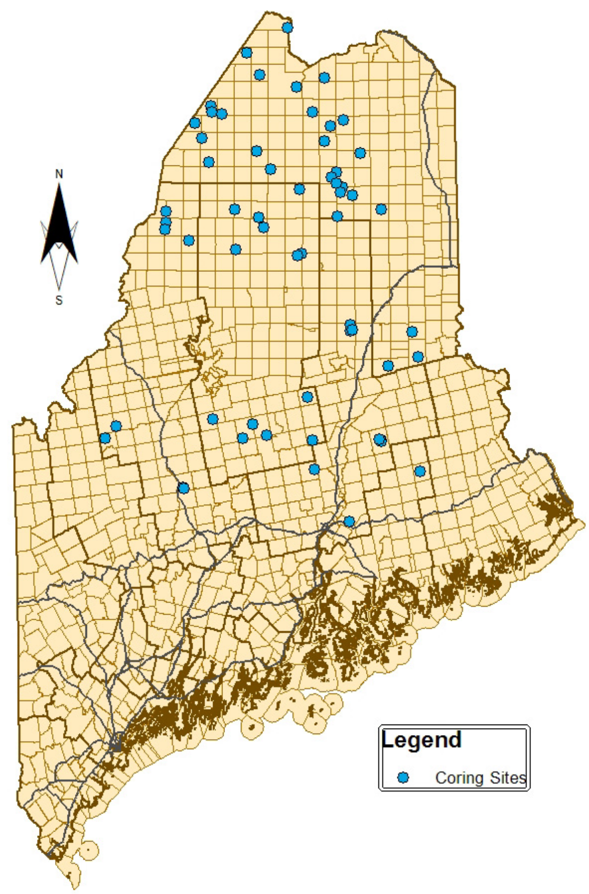

Figure 1. 60 mixed-species stands selected for growth comparison study.

At each site, five upper canopy northern white-cedar were selected, as well as five balsam fir or red spruce. If all three species were present on the same site in sufficient numbers, all three species were sampled. To be selected, each tree had to be outwardly sound and free from obvious crown damage. Light exposure (LE) class was assigned to each tree on a 1-5 scale, with class 5 being analogous to a dominant crown class, and class 1 being analogous to an intermediate crown class (after Bechtold 2003). No overtopped (LE class 0) or outwardly defective trees were sampled. Two soil pits were excavated at each site to determine site class. Site class was described using Briggs' (1994) site classes. This is a five-class scale ranging from class 1 (well drained; mottling depth >24") to class 5 (very poorly drained; mottling within four inches of mineral soil). No sites sampled had drainage exceeding site class two. In addition to these, organic or muck soils were parsed out for analysis due to inability to determine depth to mottling.

Two cores to the pith were extracted perpendicular to one another at breast height (1.3 m) of each sample tree. Cores were mounted on boards in the field, dried, sanded with 300-grit sandpaper, and read using WinDendro software. Other tree-level information obtained in the field included sapwood length for each core, diameter at breast height, total height, height to the lowest live branch, height to the base of the live crown and bark thickness. Sample data by species are provided in Table 1.

Site information was collected during the summers of 2005 and 2006. Only the most recent complete five years of growth data were used for analysis. Analysis of Covariance (ANCOVA) was used to compare basal area growth using site class, species, LE class, and sapwood area as variables with an alpha of 0.05. SYSTAT version 11 was used for all analyses.

Table 1. Tree selection by site class.

Site Class	BF[*]	RS	NWC
	Number of Observations		
2	28	10	32
3	30	15	40
4	20	30	50
5	63	58	105
Organic	30	45	70
Total	171	158	297

[*] Species abbreviations: BF-balsam fir, RS-red spruce, NWC-northern white-cedar

Results

Decay was present in all species across all drainage classes; however, there were significant differences among the species (Table 2). With such a high proportion of decay in some of the samples, it was difficult to age the increment cores. Nevertheless, we were able to detect differences in age among species. The oldest cedar observed had 222 years of readable rings at breast height, with many trees exceeding 150 years. The oldest red spruce was 201 years, with ages commonly 100-130 years. Balsam fir rarely exceeded 100 years in age, with the oldest specimen being 109 years.

Table 2: Mean proportion of cores decayed by site class (LS mean scores, SE in parentheses).

Site Class	BF	RS	NWC
	Proportion of sample decayed		
2	0.57(0.09)[a]	0.10(0.10)	0.97(0.07)[a]
3	0.40(0.08)[ab]	0.13(0.08)	0.88(0.07)[ab]
4	0.40(0.10)[ab]	0.13(0.06)	0.64(0.06)[b]
5	0.19(0.06)[b]	0.07(0.04)	0.73(0.04)[b]
Organic	0.23(0.08)[b]	0.13(0.05)	0.74(0.05)[ab]
Mean	0.34(0.03)[b]	0.11(0.02)[c]	0.80(0.03)[a]

* Means of the same species followed by different letters are significantly different at α=0.05 level. Species' means were also significantly different.

Basal area growth significantly differed among species when other variables were held constant (Figure 2). For all species, sapwood area as a covariate contributed significantly ($p<0.001$) to differences in basal area growth. In the ANCOVA model, site class was marginally nonsignificant when all species were included ($p=0.058$). Balsam fir was the only species that had significant differences in basal area growth among site classes ($p=0.013$) (Figure 3) and light exposure classes ($p=0.015$) (Figure 4).

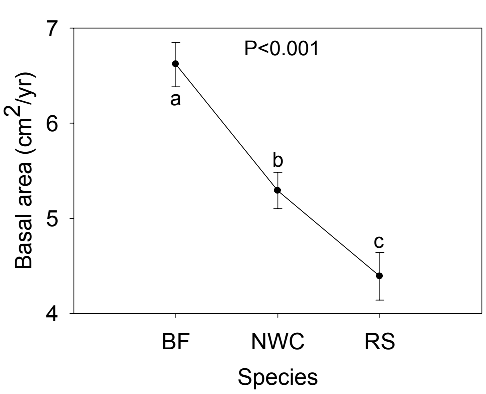

Figure 2. Basal area growth LS means by species.

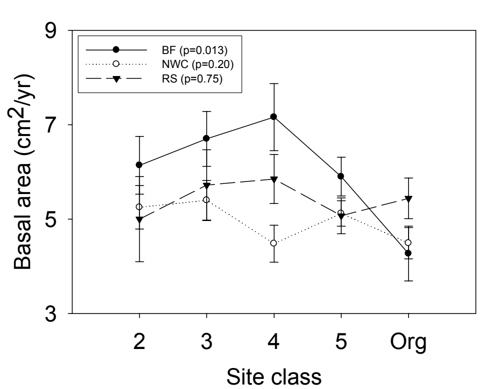

Figure 3. Basal area growth LS means by site.

Discussion

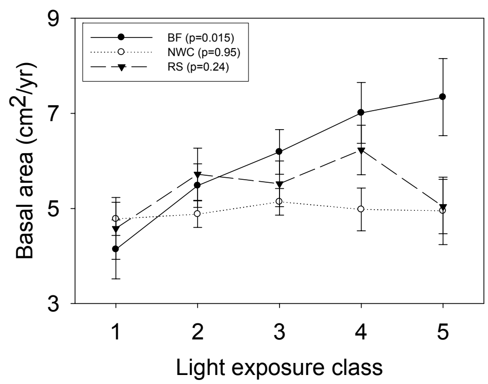

Figure 4. Basal area growth LS means by light exposure.

Conventional wisdom in Maine is that cedar trees growing on upland sites have higher growth rates and better quality (e.g. Curtis 1941). However, results from this study do not support that conclusion, at least in terms of basal area growth and soundness across site classes. A significantly lower proportion of cedar were decayed on site classes 4 and 5 than on site class 2. In Maine, upland sites are frequently partially cut, this may lead to increased root and crown damage and create entry points for fungal infection. However, a study in the Adirondacks of New York comparing bog community cedar to limestone outcrop community cedar found that approximately 80% of the stems had central decay, independent of site (Harlow 1927). Partial harvesting may also have driven species selection for the present study. Because red spruce is highly sought after, it is commonly targeted for removals on easily entered sites. Sparse upper canopy red spruce limited the number of sites useable for this comparative study, leading to a relatively small sample size that may not be fully representative of the red spruce population in Maine. Similarly, these results are biased to outwardly sound individuals of all species, which might have different mean growth rates than the Maine populations.

ANCOVA, with species, light exposure, site class, and sapwood area as variables, suggests that balsam fir will outcompete cedar and red spruce. This was not true across all site classes and light exposure classes when analysis was done by species. Additionally, cedar had a higher mean growth rate than red spruce, which was not expected. This belies the common belief that cedar has poor growth rates and thus limited management potential. Lastly, our data suggest that northern white-cedar basal area growth is not responsive to increased crown light levels. This could have major implications for managing mixed-species stands where cedar is an important component of the understory and midstory strata, and might allow foresters to take advantage of advance growth effects.

Conclusions

Northern white-cedar in Maine seem to be much older than once considered; in the present study cedar was commonly the oldest species on a given site. A high proportion of the sampled cedar was decayed (approximately 80%) with amount of decay on site classes 4 and 5 significantly lower than site class 2. Mean proportion of decay was lower in balsam fir, but increased with improved drainage. Holding all other factors constant, balsam fir had higher basal area growth rates than red spruce and northern white-cedar, and cedar growth was higher than that of spruce. This may be a function of past harvesting that left inferior spruce as residuals, but that is speculation. Overall, basal area growth was not strongly correlated with site class for red spruce and northern white-cedar. Balsam fir growth rates were influenced by light exposure class and site class, while the remaining species were not. Ongoing research is investigating northern white-cedar leaf area – sapwood area relationships, growth efficiency, and early stem development.

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Theme: Forest ecosystems

Xylem and foliar chemistry of sugar maple along a gradient of soil fertility and stand health: Is manganese involved in the sugar maple decline?

Houle, Daniel[1], Sylvie Tremblay[2] and Rock Ouimet[2]

The relationships between soil, xylem and foliar chemistry were assessed for 17 sugar maple (*Acer saccharum* Marsh.) stands that depicted a strong gradient in their soil acid-base status. There were many significant relationships between variables describing the acid-base status of the top-B soil (Ca and Mg content, exchange acidity and base saturation) and Mn concentrations and Ca:Mn and Mg:Mn ratios in xylem and foliage. Manganese concentration in foliage and xylem was an inverse non-linear function of mineral soil base saturation with a variance explanation of 69% and 63%, respectively. The 17 sites were divided into two groups according to their level of decline (% defoliation). The xylem composition trends between 1955 and 1995 were similar for every element, except for Mg. However, the declining stands had significantly higher xylem Mn and Mg concentrations and lower Ca:Mn ratios and significantly higher foliar Mn and lower Ca and Al concentrations. Although it was impossible to determine if these differences were a cause or a symptom of sugar maple health, the results suggest that the potential role of Mn in sugar maple decline might have been overlooked in the past.

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Theme: Tree physiology, carbon and nutrient cycles and genetics

Simulating the carbon budget in the boreal forest of northwestern Ontario using the Canadian Carbon Budget Model (CBM-CFS3)

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As the public is increasingly concerned by environmental issues, forest managers must consider carbon accounting (carbon sequestration and mitigation) in their management strategies. The objective of the present study was to simulate the effect of different management scenarios on carbon accounting using the Carbon Budget Model of the Canadian Forest Service (CBM-CFS3). This model, developed as a carbon accounting tool, was used to investigate the effects of different forest age-class distributions, forest types, and management scenarios on the carbon contents and fluxes of two forest types on the Dog River Matawin Forest (DRMF) in Northwestern Ontario (NWO). The DRMF (784, 700 hectares), dominated by spruce (*Picea*), pine (*Pinus*), fir (*Abies*) and poplar (*Populus*), has been actively managed for almost 100 years. For the present study, the carbon stocks and fluxes of the Jack pine (*Pinus banksiana* Lamb.) and trembling aspen (*Populus tremuloides* Michx.) forest types were simulated. The comparison of regulated and unregulated management scenarios with similar average stand ages greater than 70 years indicated that the carbon stocks of a forest in full regulation will eventually surpass those of an unregulated forest. Both forest types continuously sequestered carbon throughout the simulations regardless of the forest management scenario. The more productive trembling aspen forest type had a greater total carbon content and a greater ability to sequester carbon than the jack pine forest type.

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Theme: Tree physiology, carbon and nutrient cycles and genetics

Factors influencing the germination, emergence, and early survival of boreal, temperate and exotic Acadian forest tree species in central Maine

Kanoti, Keith G.[1] and Robert G. Wagner[2]

We examined the effects of predator protection (cage vs. no cage), sowing date (fall vs. spring), grass competition (grass seeded vs. weeded), and overstory (canopy vs. no canopy), on emergence success, timing, and rate, and first growing season survival for six native Acadian and three introduced tree species in central Maine. These species represent boreal (balsam fir, white birch and trembling aspen), temperate (red maple, red spruce and eastern white pine), and exotic (Norway maple, hybrid larch and Norway spruce) species groups. Caging and sowing date were the most important factors determining emergence success for the majority of the species. Predators reduced the emergence of eastern white pine, red maple, hybrid larch, and Norway spruce by 67%, 55%, 41%, and 44%, respectively. Except for balsam fir, which predators avoided, the degree of predation was positively correlated with seed weight. The effect of sowing date varied with species group. Fall sowing more than doubled emergence of balsam fir, and decreased emergence of hybrid larch by 37% and Norway spruce by 90%. Most patterns established by predation and sowing date were maintained through the end of the first growing season. The presence of grass and overstory canopy reduced end of growing season survival by 38% and 27%, respectively. The effect of grass on survival was independent of species. Overstory reduced survival of white birch by 72% and hybrid larch by 57%. Emergence rate and timing varied among species, but was only weakly affected by the treatments.

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Theme: Forest ecosystems

A growth and yield simulator for managed, uneven-aged northern hardwood stands in New York

Kiernan, Diane[1] and Eddie Bevilacqua[2]

An individual-tree growth and yield simulator, originally created in 1983, was updated to include long-term re-measurement data. Data were collected over a 19-year period, having up to three re-measurements, from two locations in New York State and used to create a new diameter growth equation for sugar maple (*Acer saccharum*). The individual-tree growth model was fit to 768 trees from sugar maple-dominated, uneven-aged stands managed under selection system with a variety of different residual densities and diameter distributions. The model includes future diameter as the dependent variable and initial diameter, initial stand-level basal area, and time since cutting as independent variables. Parameter estimates were obtained using a mixed linear model to account for the presence of autocorrelation between the repeated measures and for possible non-constant variances. The finite-sample corrected Akaike information criterion (AICc) was used in model performance evaluation. In addition, the model was validated and compared with the original tree growth equation using an independent data set of 183 trees and evaluated based on the mean residual, mean absolute residual and root mean square error.

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Theme: Modelling, growth and yield

Assessing soil disturbances caused by forest machinery

Labelle, Eric, R.[1]

Abstract

One of the most damaging effects caused by forest machinery is soil compaction. The normal force exerted by a machine is the basic cause of compaction. The heaviest equipment used in forestry is often a forwarder. In a cut-to-length system, forwarders also require the highest traffic volume to transport the wood from the felling site to the landings. To quantify this impact, soil density and moisture content was recorded before and after forest operations at different test sites as well as after a multi-year period to observe the influence of the freeze-thaw cycle on soil rehabilitation. A nuclear moisture-density gauge was used to determine *in situ* soil density and moisture content at 5, 10, and 20 cm depths, all measured at the same location. These readings were recorded 50 cm apart in a cross sectional direction to the forwarding trail in order to capture the foot prints of the machinery. Furthermore, soil density and moisture were monitored after different impact intensities (1, 3, 5, and 10 forwarding cycles). Preliminary results show an increase of soil density in the range of 5 to 20 % after a single forwarding cycle.

Introduction

Forest soils are an essential part of every forest ecosystem; they are anchorage substrate, water and nutrient resource for woody plants as well as habitat of a diverse fauna. The stability and productivity of forest stands are mainly related to the quality and integrity of forest soils. In order to maintain both stability and productivity of forest stands, negative impacts on soils by forest operations have to be minimized. Therefore, sustainable management practices should involve the control and prevention of unacceptable rates of erosion, nutrient loss, landslides, excessive compaction, puddling and mixing of topsoil and subsoil, during and after forest operations (Forest Practices Board 2000). One of the most damaging effects caused by forest machinery is soil compaction which is defined as an increase in bulk density (increased mass per unit of volume) (Dickerson 1976). Soil densification has a direct impact on plant and tree growth since it reduces the water infiltration rate and slows down gas and nutrient exchange by decreasing the amount of pore space, especially macropores (Forristall and Gessel 1955). The highest degree of compaction typically occurs in the top 30 cm of a soil profile, which normally contains most of the root mass (Wingate-Hill and Jakobson 1982). All these modifications of the soil structure may considerably reduce vegetation growth. After subsoil compaction, Murphy et al. (2004)

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reported that reduced growth resulted in a 42 % decrease of stand volume which translates to a 60 % decline in value.

Nowadays, most forest operations require the use of heavy machinery in order to be competitive. The Canadian forest industry performs two main felling and extraction methods, the cut-to-length (CTL) and tree length methods. CTL logging is a system for mechanized forestry harvesting where trees are delimbed and cut-to-length directly at the stump area. This system has been utilized in Canada since the 1970’s but has gained much popularity especially in the Atlantic provinces over the past decade where more than 75 % of the wood is currently being harvested with the CTL method.

Forwarders as part of the CTL harvesting system are among the heaviest equipment used in forestry ranging from 15 to 40 tons loaded and are the ones that require the highest traffic volume in order to transport wood from the felling site to the landing areas. The payload of the forwarder determines its productivity. Increasing this parameter without increasing the area of contact can expand the environmental risk caused by the machine (Nugent et al. 2003).

Soil susceptibility to compaction is dependent on many intrinsic properties such as soil texture (Bodman and Constantin 1965), parent material (Wasterlund 1985) and moisture retention properties (Vepraskas 1984). Directly related to this susceptibility is the rehabilitation capabilities of a soil after disturbance which are dependent on soil structure, texture, moisture content as well as severity and depth of compacted area (Brais 2001). Forest soils are not only sensitive to disturbances but may also require a long time to rehabilitate. Residual forest soil compaction has been reported for periods ranging from 15 (Froehlich et al. 1986) to 55 years (Power 1974).

Research is therefore required to evaluate the degree of compaction caused by CTL forest machinery on forwarding trails over a multi-year period with respect to different equipment configurations, transport cycles and site conditions. The research project described in this article aims at determining the impact of forest machinery on soils by measuring soil density and moisture content before and after harvesting and forwarding. In addition, it analyses the degree of soil recovery with regards to soil density from disturbance of forest machinery after a multi year period compared to the properties measured before and after the disturbance.

Materials and methods

The field work for this project commenced in July 2004 and will continue for several years. The disturbances caused by CTL forest operations will be analyzed on different forwarding trails by measuring soil density and moisture before and after forest operations.

Forest machinery

When considering operational variables, forwarders vary in tare-weight from 7 to 20 tons. Since the tare-weight of the machinery is stable and can not be modified without structural changes, this study focuses on the ground pressure created by the equipment (Table 1).

Table 1. Machinery specifications for each research site

Research sites	Make and Model	Traction type		Empty mass (kg)	Load capacity (kg)	Loaded mass (kg)	Ground pressure (EMPTY)		Ground pressure (LOADED)	
		Rear Axle	Front axle				Front (kPa)	Rear (kPa)	Front (kPa)	Rear (kPa)
Blk. 250	Tigercat H822 [1]	R.S.T		26, 490	**N/A**	**N/A**	60.4		**N/A**	
	Rottne Rapid [2]	S.F.T	Chains	14, 200	16, 000	30, 200	61	30	78	92
Blk. 257	John Deere 120 [1]	R.S.T		18, 379	**N/A**	**N/A**	40.5		**N/A**	
	Timberjack 610 [2]	F.T	F.T	12, 800	8, 000	21, 800	43.4	34.5	49.6	88.3

[1] = Harvester **S.F.T** = Steel flexible tracks **R.S.T** = Rigid steel tracks
[2] = Forwarder **F.T** = Flotation tires (109 cm wide) **N/A** = Not applicable

Field sampling and measurements

In each cut-block (250 and 257), a forwarding trail of ± 190 m in length and 5 m wide was designed prior to forest operations (Figure 1). Along the forwarding trail, four compartments were established to analyze the impact of traffic intensity on soil compaction. This was done by varying the number of forwarding cycles i.e. one cycle is one pass-over without a load and one pass-over with the log bunk filled with wood. Each of these compartments was 5 m wide and 20 m in length. Soil density and moisture was measured in each compartment perpendicular to the axis of the forwarding trail at locations systematically spaced 50 cm apart along the full width of the trail in order to capture the foot prints of the machinery that was going to be driven over the area. In total, nine measurements (which constitute a line) were recorded across the forwarding trail and a total of four lines were studied per compartment. These lines were grouped in pairs spaced by one meter and 15 m between each pair. Adjacent to each pair of lines were control zones consisting of two lines of four measurement points per line that remained undisturbed throughout the study. At each measurement point, *in situ* soil density and moisture content was determined by a nuclear moisture-density gauge at 5, 10, and 20 cm depths, all measured at the same location. After the initial pre-harvest readings were completed, the block was harvested with the equipment described in (Table 1) and special care was given to keep the trail free of any slash in order to determine the maximum impact of the equipment. A single pass over with the harvester was allowed inside each forwarding trail. Once the wood was harvested, different traffic intensities (forwarding cycles) were simulated by driving the forwarder a certain number of times over the compartments (1, 3, 5, and 10 times) without a load and with a full consistent load. A set of measurements was recorded in each block before and after harvesting and forwarding as well as in the following spring and summer.

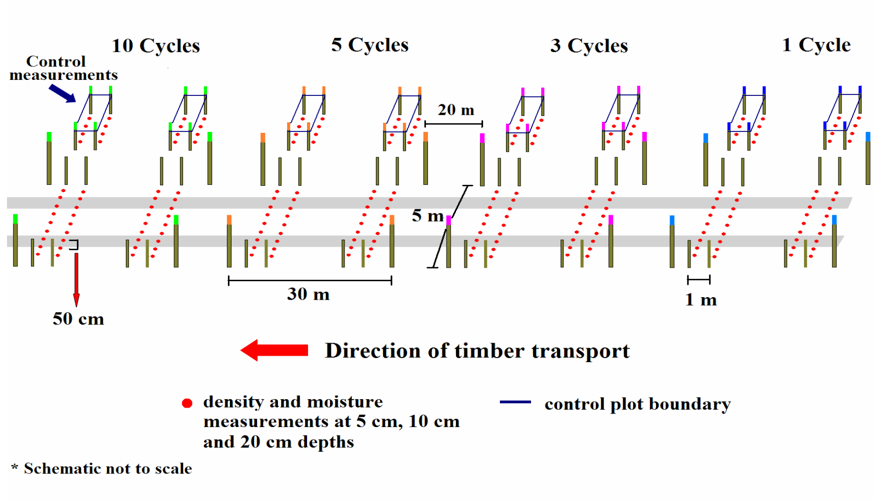

Figure 1. Forwarding trail and sampling layout of block 250

Nuclear moisture-density gauge

This research focuses on a non intrusive, *in situ* method of determining soil moisture and density by using a nuclear density gauge, more specifically the Humboldt 5001 EZ model. This equipment automatically computes a variety of parameters. For this research emphasis is given to wet and dry density as well as moisture content of the soil. The density measurement is based on the attenuation of gamma radiation due to Compton scattering and photoelectric absorption directly related to the electron density of materials (Humboldt Scientific 2000). The sensor that collects the backscattering of gamma radiation is located at the bottom of the nuclear moisture-density gauge itself which is placed on the ground. As for the moisture content, its measurements are based on the thermalization of fast neutron radiation, which is a function of the hydrogen content in the materials. Both source and sensor for neutrons are located at the bottom of the nuclear gauge (Humboldt Scientific 2000).

Results and discussion

Since this is an on-going research project and part of the data was recently collected, what follows are preliminary results originating mostly from block 257.

Soil density

The difference between pre and post harvest lines perpendicular to the forwarding trail show an increase in dry density where the machinery made contact with the soil both at the 5 and 20 cm depths (Figure 2). There is no statistical difference (P = 0.141, N = 10) between pre and post harvest dry density readings underneath the tires at a 5 cm depth. Furthermore, there is no statistical difference between the compaction caused by the machinery at the 5 cm and 20 cm depths (P = 0.919, N = 10). However, there is a statistical difference (P = 0.010, N = 10) between pre and post harvest dry density readings located underneath the tires at a 20 cm depth. The root and stump network found in forest soils can act as a complex pivotal system that can increase ground pressure on one side and provide a certain counter-effect at the opposing end of the root.

Consequently, the pressure applied by a forwarder's tire could possibly be displaced vertically thus increasing the disturbed area.

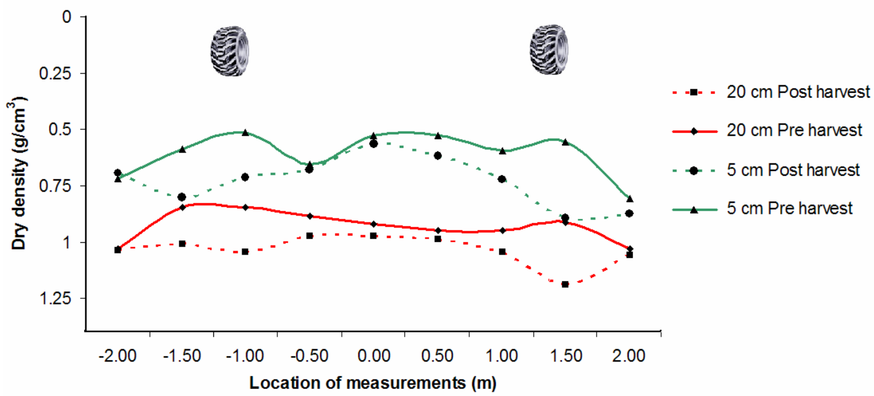

Figure 2. Pre and post harvest soil dry density (g/cm^3) in relation with the location of measurements on the forwarding trail for cycle 3 (line 1 and 2) of block 257

In the majority of the cases, compaction occurred at all three depths of measurements with the exception of the cycle 10 compartment. The soil in cycle 10 (block 250) had very high water content (59 % at 20 cm to 110 % at 5 cm depth) when post harvest readings were recorded. Furthermore, even though block 250 was a winter harvest (Jan. 2006), severe ruts (35 to 50 cm in depth) were created in the compartment where 10 forwarding cycles were studied. In this compartment, plastic deformation of the soil was the main effect of the pressure applied by the equipment and not compaction itself. Concerning block 257, a statistical difference was found at the 20 cm depth between pre and post harvest readings after a single cycle. In the same block, a statistical difference was found at the 10 and 20 cm depth following 3 forwarding cycles. The average compaction, all depths combined was 12.2 % and 15.6 % respectively after 1 and 3 cycles. With regards to block 250, very little compaction (3.9 %) was caused after the first forwarding cycle while close to 18 % was recorded after 5 cycles at the 20 cm depth.

Soil rehabilitation

Soil density tends to increase linearly as depth increases (Figure 3). This is true for up to 20 cm depth in this study. The degree of compaction (post harvest – pre harvest) seems to be similar between 1 and 3 cycles although initial dry density was lower in cycle 3. Soil rehabilitation is more pronounced in cycle 3 than cycle 1. In order to understand why this trend is occurring, moisture content and organic matter content were added to the graph. Moisture contents of spring readings are higher in cycle 3 than cycle 1, 55 % to 34 % respectively which reduces soil dry density. Furthermore, the 5 cm layer in cycle 3 has a high organic matter content (57 %) compared to cycle 1 at 15 %. Organic matter has a high water retention capability and a low specific gravity (± 0.80) which can influence the moisture content readings of the nuclear gauge which then impacts the dry density.

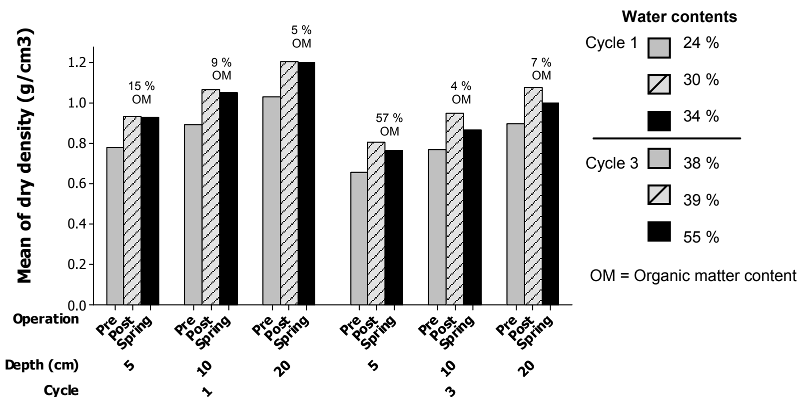

Figure 3. Temporal variation of soil dry density (g/cm^3) located under tires in relation with different depths and forwarding cycles for block 257, line 1

Conclusions

Economically feasible operations rely on the use of heavy equipment to harvest and transport wood from the felling site to the landings. Forwarders used in the CTL method are the heaviest equipment used in forestry and have the highest traffic volume making them a high risk to cause soil disturbances. This study showed that a single forwarding cycle created a 12.2 % increase in soil dry density within the first 20 cm of soil. However, there was no statistical difference between cycle 1 and cycle 3 with regards to soil compaction. The best method to minimize ground disturbances is to conduct forest operations when the soil water content is low in order to keep compaction and plastic deformation at a minimum.

Acknowledgements

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Theme: Forest management, operations and engineering

The environment of ericaceous shrubs in forest ecosystems of the Quebec North Shore

Laberge-Pelletier, Caroline[1] and Alison D. Munson[2]

The rapid development of ericaceous shrubs after clearcutting appears to hinder the regeneration of black spruce in forest ecosystems of the Quebec North Shore. The objectives of this project were: (1) to quantify the presence of ericaceous species in stands originating from natural disturbances in forest ecosystems of the Quebec North Shore, (2) to study the relationship between environmental variables and the presence of ericaceous shrubs, and (3) to identify the most important vegetation associations in these forests. This study was conducted in the boreal forest of eastern Quebec, Canada **(**50°68'51" N, -68°79'62''W**),** north of Baie-Comeau. Ninety-seven sites within the black spruce-feathermoss forest type were selected for the study. Black spruce was the main species in the majority of the sites. In each stand, a circular plot of 400 m^2 was randomly located. Results showed that *Vaccinium* species *(Vaccinium angustifolium* Ait., *Vaccinium vitis-idaea* L. and *Vaccinium myrtilloides* Michx.) were the most frequently found ericaceous species, followed by *Rhododendron groenlandicum* (Oeder) Kron and Judd and *Kalmia angustifolia* L. *Rhododendron* had the highest mean cover, followed by *Vaccinium* and *Kalmia*. Canopy opening size, stand type, soil texture and native species type were associated with the presence of ericaceous species in uneven-aged forests of the Quebec North Shore region. Extensive cover of *Rhododendron, Vaccinium, Kalmia*, and lichens (*Cladina* spp*.)* were found in low density black spruce-feather moss stands. Prior to harvest, there was also a vast cover of these species in the dense stands, suggesting a potential problem with ericaceous shrubs after canopy opening. *Rhododendron, Vaccinium, Kalmia*, and *Cladina* were associated with sites characterized by poor humus decomposition, low nitrogen mineralization rate and acid and nutrient-poor mineral soil. Four vegetation associations were identified. The environmental factors and plant indicator species found in this study can now be used for classifying the stands according to their vulnerability to ericaceous invasion prior to harvesting.

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Theme: Forest ecosystems

Temporal and spatial quantification of fine sediment accumulation downstream of culverts in brook trout habitat

Lachance, Stéphanie[1], Maryse Dubé[2], Renaud Dostie[2] and Pierre Bérubé[2]

We quantified fine sediment accumulation in five brook trout streams on the Laurentian Shield for three to four autumns following culvert construction. The significant spatial pattern (section effect) was that of the lowest accumulation upstream of the culvert, a peak of accumulation at section 2 directly below the culvert and slight decrease for sections 3 to 5, not returning however to upstream levels. The accumulation was always significantly higher downstream of the culverts than at upstream sections. The significant temporal pattern (period effect) was that of the lowest accumulation several weeks following construction, a peak of accumulation one full year after construction with a decrease after 2 and 3 years. The accumulation was significantly different between all periods. Because of large differences between regression models, it was impossible to predict the downstream distance where fine sediment concentration recovered the levels found upstream. However our best fit models predicted distance between 250 and 1,500 m. Because of the accumulated sediment, mostly originating from construction sand or road erosion, the habitat found downstream of the culverts is definitely of lesser quality for brook trout incubation and rearing in many cases. Recommendations to minimize culvert impacts on aquatic habitat are discussed.

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Theme: Wildlife

The effect of Pre-commercial thinning (PCT) on the abundance of herbaceous species

La France, Kerienne[1] and Mark R. Roberts[2]

Abstract

Pre-commercial thinning (PCT) is an intermediate treatment employed in young stands following harvest. While the effects of PCT on wood production are fairly well documented, the effect of PCT on herbaceous species is not fully understood. The objectives of this project are: 1) to compare species abundance, stand-level characteristics and fine-scale environmental features between PCT stands and un-thinned controls; 2) to identify relationships between plant species abundance and possible causal factors including stand-level and fine-scale environmental features; and 3) to determine if any inherent plant characteristics influence species' response to changes in environmental conditions associated with PCT. Treated PCT sites and comparable un-thinned controls were sampled in three age classes: 5, 10 and 20 years after PCT. Mean cover of fine woody debris and tree litter was higher in PCT stands than in the controls in the 5 year age class; however, both of these habitat features were comparable between PCT and controls 20 years after treatment. Changes in the cover of ferns, shrubs and herbs after PCT suggest that thinning may create environmental conditions in which tall-growing species may have a competitive advantage over low-growing species, and also implies that light availability may be a driving factor in species response to PCT.

Introduction

Pre-commercial thinning (PCT) is an intermediate treatment employed in plantations and naturally regenerating stands following harvest and is usually applied when trees are young, before canopy closure occurs (BC Environment 1995, Nyland 1996). Since PCT has become an important tool in wood production, it is important to understand the impacts of this treatment on other ecosystem components. The herbaceous layer includes all vascular herbs and shrubs less then one meter in height. Herbaceous species are of particular interest because they play an important role in nutrient cycling and energy flow (Roberts and Gilliam 2003) and represent the majority of plant species diversity in forest stands.

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Unlike stand-initiating disturbances such as clearcutting, intermediate stand treatments such as PCT tend to cause fewer disturbances to the forest floor and may in turn, have fewer impacts on herbaceous species. Generally, it has been found that plant diversity increases approximately 10 years after PCT (Alaback and Herman 1998, Sullivan et al. 2001, Thomas et al. 1999). He and Barclay (2000), however, report that the effects of thinning on diversity do not persist as stands mature. They found no differences in species richness or composition between thinned and un-thinned sites 27 years after treatment. The increase of species diversity after thinning may be due to reduced tree canopy cover which has been shown to be a good predictor of understory cover (Klinka et al. 1996).

Indeed, there are numerous environmental factors which may influence vegetation cover, including woody debris (Homyack et al. 2004, Sullivan et al. 2002, microtopography (Beatty 1984), microclimate, and competition from tree seedlings (Davis et al. 1998) all of which are directly affected by thinning activities. Previous studies (Homyack et al. 2004, Sullivan et al. 2002) indicate that cover of fine woody debris (FWD) and coarse woody debris (CWD) increases after PCT; however, these changes do no persist over time (Sullivan et al. 2001).

In addition to environmental factors, changes in species composition may also be related to the inherent characteristics of the plants themselves, such as shade tolerance and dispersal mechanisms. For example, thinned stands have been shown to have higher frequencies of late-seral species than un-thinned sites, due to the ability of these species to expand across the site while the canopy is open and then persist when canopy closure occurs (Alaback and Herman 1998, Lindh et al.2004).

The specific objectives of this project are: 1) to compare species abundance, stand-level characteristics and fine-scale environmental features between PCT stands and un-thinned controls; 2) to identify relationships between plant species abundance and possible causal factors including stand-level and fine-scale environmental features; and 3) to determine if any inherent plant characteristics influence species' response to changes in environmental conditions associated with PCT.

Methodology

Treated PCT sites and comparable un-thinned controls were sampled in three age classes: 5, 10 and 20 years after PCT (15, 20 and 30 years after harvest) (Table 1). The study areas were located in central New Brunswick and include crown land near Coles Island (45º 95' N, 66º 83' W) and the Acadia Research Forest (ARF) (45º 96' N, 66º 47' W), approximately 22 km east of Fredericton. Study sites were classified as Ecosite 2 and were characterized by moist soils dominated by spruce (*Picea sp.*). All sites were clear cut and allowed to regenerate naturally without the application of herbicides or fertilizers. Treatment (PCT) sites were thinned 10-15 years after harvest while comparable controls had not received a thinning treatment. Stands were located using GIS records provided by J.D. Irving Ltd. and were a minimum of three ha in size.

Data were collected during the growing seasons of 2005 and 2006. Four 300m transects, 20-50 m apart, were established within each stand. Twelve to thirteen 1m² quadrats were randomly located along each transect for a total of 50 quadrats per stand. Vegetation variables measured within each quadrat include the number and percent cover of tree seedlings and the percent cover of shrub and herb species. Percent cover was visually estimated and included all vegetation <1m in height. Percent cover of fine-scale environmental features describing slash (hardwood and softwood FWD), substrates (mineral soil, humus and litter), and ground disturbance (cover and depth of tracks) were also measured. Hardwood and softwood canopy cover above each quadrat was estimated for each quadrat using a spherical densiometer. Readings were taken from all four sides of the quadrats at a height of 1m and were averaged to determine the average canopy cover for each stand.

The volume of coarse woody debris, residual tree density, tree species, diameter, and tree height were sampled in six 5.64m fixed radius sample plots per site. The volume of CWD was recorded at each plot using the perpendicular distance sampling method (Williams and Gove 2003). The height of one representative tree within each sample plot was measured using a clinometer to provide an estimate of average tree height for each stand.

Table 1: Total number of sampled PCT and control sites for the 2005 and 2006 field seasons for each age class (5, 10 and 20 years PCT).

Treatment	Age Class		
	5	10	20
PCT	**8**	**9**	**9**
Control	**5**	**5**	**5**

Preliminary results

Preliminary results from analysis of the 2005 data show some general trends in the species and environmental data, although data were not yet collected from the 10-year controls due to time limitations. Mean cover of FWD and tree litter was higher in PCT stands than in the controls in the 5 year age class; however, both of these habitat features were comparable between PCT and controls 20 years after treatment (Figure 1).

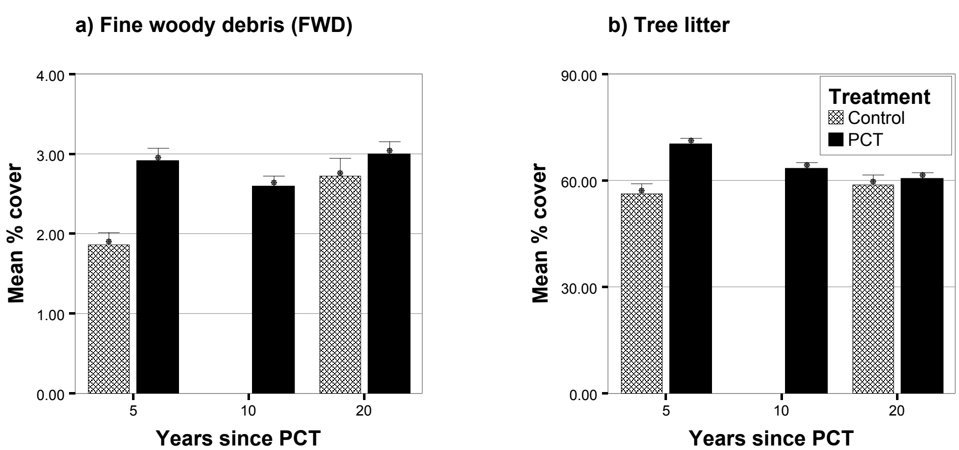

Figure 1: Mean percent cover (± 1.0 SE) of fine-scale environmental features by age and treatment: fine woody debris (FWD) (a); and tree litter (b).

Mean species richness (number of species per stand) appeared to be higher in PCT stands than in un-thinned controls and seemed to decrease over time; however, these differences were not statistically significant (P = 0.385, α = 0.05) (Figure 2). Species were categorized by growth form based on descriptions from the literature. The growth forms include herbs, ferns, fern allies, graminoids, tall shrubs > 1m, low shrubs < 1m, sub-shrubs (creeping species with partially woody stems), and trees. Mean percent cover of growth forms were plotted for each age and treatment (Figure 2). Mean percent cover of ferns and tall shrubs were higher in PCT stands than in controls five years after treatment. Herbs on the other hand, were lower in PCT stands than in controls five years after treatment. The cover of both ferns and herbs were comparable between the two treatments 20 years after PCT. Other growth form data were insufficient for analysis.

Discussion and conclusions

Preliminary results suggest that several fine-scale habitat features are influenced by PCT. An increase in FWD in PCT stands was expected since debris is left on site after treatment.The increase in litter may be due an increase in canopy cover in response to PCT. Preliminary results also indicate that PCT may also influence species composition. Contrary to previous studies, the

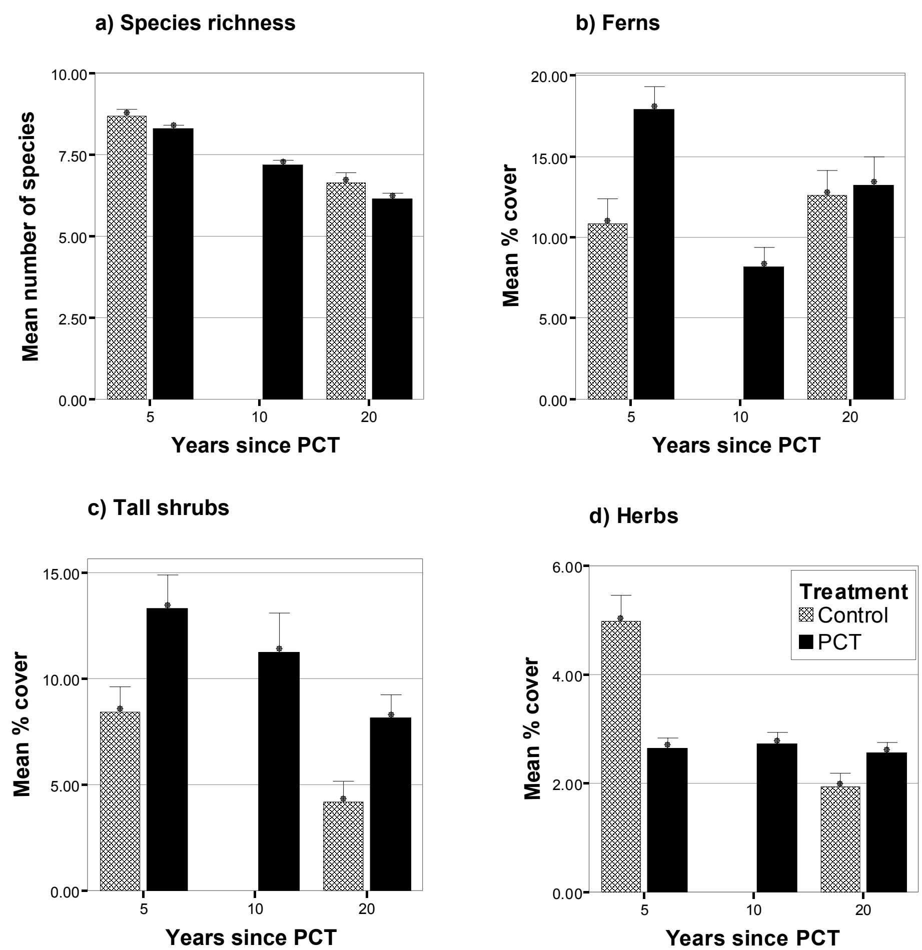

Figure 2: General vegetation patterns by age and treatment: mean species richness (± 1.0 SE) (a); mean percent cover of ferns (b); tall shrubs (c) and herbs (d).

percent cover of some species groups were different in PCT stands compared to controls only five years after treatment. Changes in the cover of ferns, shrubs and herbs after PCT suggest that thinning may create environmental conditions in which tall-growing species may have a competitive advantage over low-growing species, and also implies that light availability may be a driving factor in species response to PCT.

In conclusion, the cover of several environmental features and growth forms appears to be similar between PCT and control sites in mature sites (20 years after PCT) which implies that for some variables, the long term effects of PCT may be minimal. Further examination of these environmental variables and individual species using the 2006 data will be done to determine if PCT has any long-term effects on environmental features or species abundance.

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Theme: Silviculture

Optimizing hardwood tree establishment in recently abandoned agricultural fields: The effects of treeshelters under different environmental gradients

Laliberté, Etienne[1], Alain Cogliastro[2] and André Bouchard[3]

In eastern North America, abandonment of agricultural land often leads to the development of herbaceous communities that are highly resistant to tree invasion, mainly because of strong competition for water. Therefore, when establishing hardwood tree plantations in such conditions, site preparation, as well as chemical or mechanical vegetation control, is strongly recommended. However, these methods can sometimes be ecologically or socially inappropriate. In this context, could tree establishment be "artificially facilitated", in a similar way that tree seedling growth can be facilitated under the canopy of certain woody plants ("nurse plants") in herbaceous communities? Our objective was to test, in a herbaceous field, whether such "artificial facilitation" could be obtained with treeshelters, which are known to reduce available light and improve tree water relations. We tested this hypothesis on three species (*Acer saccharinum*, *Fraxinus pennsylvanica*, and *Quercus macrocarpa*) in a recently abandoned field in Parc national des îles-de-Boucherville (Quebec). We found that treeshelters could facilitate tree growth but that this facilitation, when present, was due to a shift in leaf morphology and not to an improvement in leaf water relations. Also, the effect of treeshelters varied (being sometimes positive or negative) along certain environmental gradients. Treeshelters facilitated tree growth when the surrounding herbaceous biomass was low (high light availability), but inhibited growth when the surrounding herbaceous biomass was high (low light availability).

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Theme: Silviculture

Is harvesting *Taxus canadensis* sustainable?

Lamontagne, Manuel[1] and Sarah Martin[2]

Foliage of Canada yew (*Taxus canadensis* Marsh.) is harvested for extracting chemicals used in anticancer pharmaceutical products. According to New Brunswick guidelines, only the last three years growth of four out of every five branches are harvested. A randomized-complete-block design was established in northwestern New Brunswick to determine if this harvesting method is physiologically sustainable for the plant. According to the literature, harvesting is sustainable if less than 50% of net photosynthesis is removed. Net photosynthesis (µmol g^{-1} s^{-1}) was measured on zero (current) to 5-year-old foliage in June, July and August 2004 to determine the contribution of each needle age class to the photosynthetic budget of the plant. Total biomass of each needle age class (0 to 5 and > 6 years old) was measured in May 2005 to simulate the impact of foliage harvesting on percentage of biomass removed and on photosynthetic budget. When following guidelines, harvesting removed 35 to 39% of the foliage biomass of the last three years' growth. However, only 24 to 36% of net photosynthesis was removed since net photosynthesis decreased with increasing needle age classes. According to our hypothesis, the harvesting method used in New Brunswick is physiologically sustainable.

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Theme: Tree physiology, carbon and nutrient cycles and genetics

Structure, composition, and productivity of riparian forests in Quebec

Landry, Catherine[1,2], Marcel Darveau[2,3] and David Pothier[4]

In the boreal forest of eastern Canada, riparian zones are under increasing pressure related to forest management, hydroelectric development, ecotourism, etc. However, the classification, the description of the structure and, consequently, the current methods of protection of the riparian ecosystem remain primitive. To improve the management of these zones, it is of primary importance to distinguish the various parts of the riparian areas in regards to the structure, the composition and the productivity of the forested riparian zones. Our project aims at providing a portrait of the riparian zones of the various natural regions in boreal Quebec, using two approaches. The first consists in describing the horizontal structure of the riparian zones (width) and its composition by using provincial numerical forest inventory. Second, we established forest inventory plots to determine if forest productivity differs between riparian areas and comparable non-riparian sites. Preliminary results suggest that the riparian areas of the various natural regions present differences in structure, composition and productivity that could be related to certain factors such as the geographical position of the natural regions, the type of soil deposit and the topography associated with these various areas.

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Theme: Forest ecosystems

Validating forest productivity models is an essential milestone of model development: A case study of the validation of ZELIG for balsam fir-red spruce-yellow birch and yellow birch-sugar maple-balsam fir mixedwood ecosystems in southern Quebec

Larocque, Guy R.[1], Louis Archambault[2] and Claude Delisle[2]

Several forest succession models have been developed in the last few decades. However, very few validation exercises have been conducted with existing models, particularly the type of validation that consists in comparing predictions with observations. One of the reasons that explain this situation is the lack of long-term historical data for forest ecosystems. Model validation is an essential milestone of model development because logical inconsistencies may be detected or new directions may be suggested. The validation of the ZELIG model for balsam fir-red spruce-yellow birch and yellow birch-sugar maple-balsam fir mixedwood ecosystems using long-term remeasurement data obtained from sample plots located in the Mauricie National Park, Quebec, Canada, suggested new directions for the description of individual-tree competition. An important feature of ZELIG is the concept of zone of influence that represents the space within which individual trees compete for site resources. Predictions were compared with long-term observations and a sensitivity analysis to variation in the size of the zone of influence was conducted. There was relatively good agreement between observed and predicted basal area for nearly all species. However, for several species, the degree to which model outputs were in good agreement with observations depended on the variation in the size of the zone of influence.

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Theme: Modeling, growth and yield

Juvenile development of fast-growing mixed plantations of hybrid poplar clones and genetically improved spruces in Abitibi-Temiscamingue

Larocque, Guy R.[1], Jean Beaulieu[2], Robert Boutin[2], Gaëtan Daoust[2], Francine Tremblay[3], Annie Desrochers[4], Suzanne Brais[3] and Stéphane Gaussiran[5]

Local communities and private forest industries are increasingly interested in the implementation and management of large-scale fast-growing species plantations to meet the increasing fibre need for wood-based products and energy production. Hybrid poplar clones and genetically improved spruces have the potential to meet these needs. However, much information still must be acquired to evaluate their economic feasibility, identify the hybrids and genetically improved spruces that are best adapted to regional conditions, and determine the optimal management regimes. For these reasons, experimental designs were implemented in 2002 and 2003 in different regions of Abitibi-Temiscamingue to compare the productivity of hybrid poplar clones and genetically improved white spruce (*Picea glauca*) and Norway spruce (*Picea abies*) in both pure and mixed plantations. The early growth results indicated significant differences in absolute growth rate (AGR) for root collar diameter and stem height among clones and genetically improved spruces in pure plantations. Significant differences were also obtained for root collar AGR among sites, but for the same clone. In some cases, three-fold differences in root collar diameter AGR were obtained for the same clone located on different sites. Differences in AGR for root collar diameter and stem height were less pronounced in mixed plantations. These preliminary results suggest that several hybrids and genetically improved spruces will perform well in the growth conditions of Abitibi-Temiscamingue.

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Theme: Tree physiology, carbon and nutrient cycles and genetics

Regeneration of *Thuja occidentalis* L. in mixedwood stands on mesic sites after partial cuts in Quebec

Larouche, Catherine[1], Jean-Claude Ruel[2], Jean-Martin Lussier[3], and Laura Kenefic[4]

Abstract

Concerns have been expressed regarding a decrease in the abundance of cedar. Possible reasons for this reduction include poor harvesting methods and an increase in animal browsing. This study attempts to examine the favorable conditions for germination, establishment, and growth of cedar regeneration. The experimental design comprised four cover reduction treatments, two browsing control treatments, two seedbed disturbances, and three regeneration types for cedar. Light, humidity, temperature, and seed rain were also monitored for two years. Results show that cedar establishment and survival are better under low light intensity, but sapling height growth is best with full illumination. Disturbed seedbed, artificial seeding, and animal exclosure increase the abundance of cedar regeneration.

Introduction

In the province of Quebec (Canada), an important part of the supply of eastern white-cedar comes from mixedwood stands that are often harvested by the selection system. However, little is known about the sustainability of this practice for cedar. In fact, cedar is one of the least studied commercially valuable trees in the United States and Canada, despite its occurrence among a wide variety of habitats (Scott and Murphy 1987). This is a disconcerting situation, given the ecological and economical importance of this species (Heitzman et al. 1999). A major concern for cedar management is the very restricted distribution of cedar reproduction after harvesting (Gringal and Ohmann 1975; Johnston 1990). Factors that can hinder cedar regeneration success include inadequate seedbeds, browsing by deer, hare and other rodents, and competition with faster growing species (Johnston 1990). The objective of this project is to get basic information about the factors limiting cedar regeneration in order to develop adequate silvicultural approaches.

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Methods

Three uneven-aged yellow birch and softwood stands were selected approximately 120 km northwest of Fort-Coulonge in western Quebec, Canada (46°51'N, 77°23'W). The study area is in the balsam fir-yellow birch bioclimatic domain. Study stands were selected on the basis of a significant cedar component growing on mesic conditions, and because they had not been harvested recently (partial cut in 1969). Four 8-ha blocks were established in 2004. Four 2-ha cover reduction treatments (control, 25% single-tree selection (S25), 50% seed cut (S50), and rectangular gaps of 625 m^2) were applied in each block. The balanced factorial design combines two browsing control treatments (with vs. without exclosure), two seedbed types (disturbed vs. undisturbed), and three regeneration methods for cedar (natural seeding, artificial manual seeding, and planting with four 3 year-old (1+2) saplings). Regeneration of all species was counted yearly in each 4-m^2 seeding plot (256 plots). Growth of cedar plants was monitored in August 2004, 2005, and 2006 (128 plots; 512 saplings). Seed dispersal was monitored on an annual basis (64 1-m^2seed traps). Seedbed properties were determined in 16 plots: soil temperature at 6 cm deep was monitored every 2 hours with WatchDog^{MC} probes, soil humidity was monitored once a month with TDR probes, and nutrient availability was assessed with PRS probes. Light availability was estimated from hemispherical photographs (64 plots). Foliar analyses will also be conducted to relate sapling nutrition and seedbed type (512 saplings).

Results and discussion

The abundance of cedar seedlings has been influenced by cover reduction treatments and time since harvesting (Figure 1). Control and S25 had the highest abundance of cedar regeneration in 2006. Light availability may increase cedar regeneration abundance (Rooney et al. 2002), but all treatments had received enough light to allow establishment. Shade is necessary to maintain the soil moisture and temperature at an acceptable level to avoid seedling mortality. Seedbed moisture is inversely proportional to the canopy opening, thus partial shading mitigates extreme temperatures and keeps soil moist (Johnston 1990; Raymond et al. 2003). In gaps, the growth of cedar regeneration has been inhibited by high soil temperature, low soil moisture, and full light conditions (Johnston 1990; Raymond et al. 2003). Thus, cedar seedling desiccation and mortality was the highest.

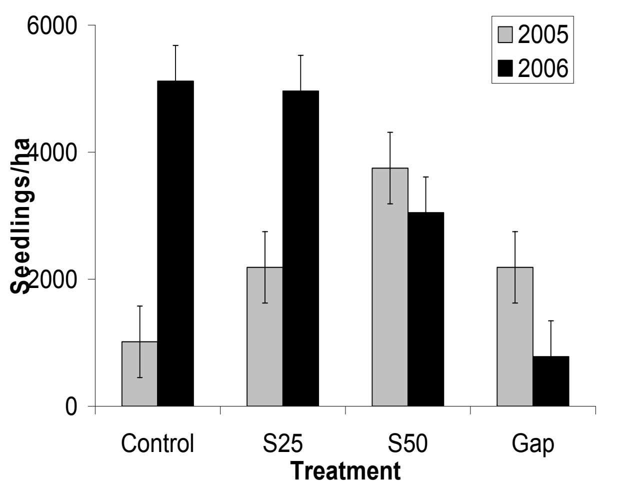

Figure 1. Mean abundance of cedar regeneration per hectare in control and canopy reduction treatments. ($p<0.001$).

In 2005, natural seed dispersion onto the plots was very poor with a mean of 6 seeds/m^2. To clarify the distinction between inadequate seedbed and lack of cedar seeds, artificially seeded plots have been flooded with 250 seeds/m^2 (2005) and 500 seeds/m^2 (2006). Cedar regeneration monitored was higher on all seedbed types and cover reduction treatments on areas artificially seeded relative to natural seed rain (Figure 2). Only plots without cutting had the same cedar abundance for both seeding types (Figure 2b). Heitzman et al. (1997) found that the abundance of cedar regeneration was highest on recently disturbed seedbeds (Figure 2a). Scarification favors the establishment of species with small seeds (Raymond et al. 2003),

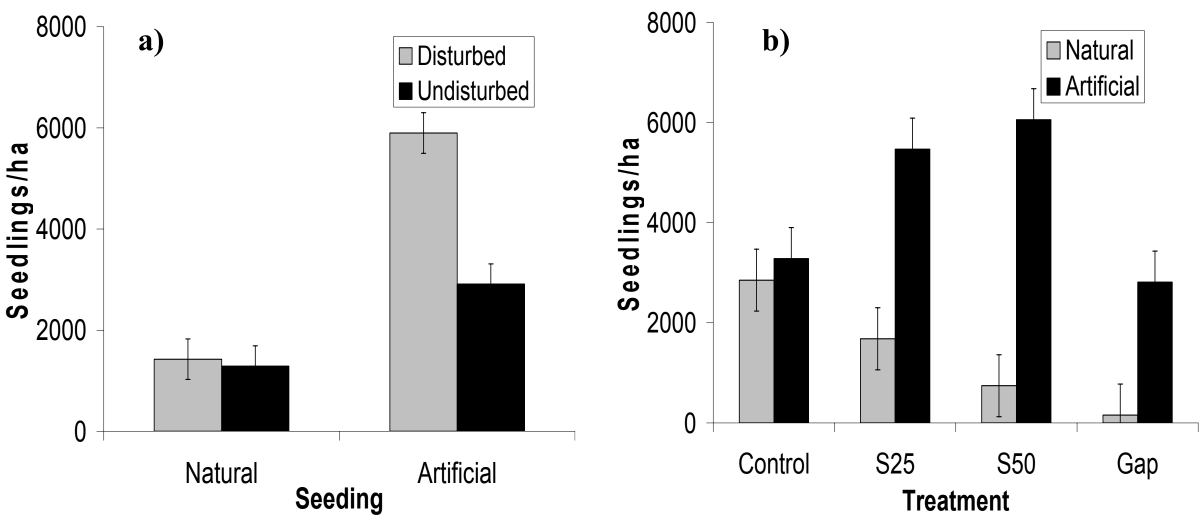

Figure 2. Mean abundance of cedar regeneration per hectare with natural and artificial seeding on a) disturbed and undisturbed seedbeds (pr=0.009), b) all canopy reduction treatments (pr=0.018).

because the humus is difficult for seedling roots to penetrate. However, the results of the present study suggest a relationship between artificial seeding and cedar regeneration abundance. Artificial seeding could be used to supplement an inadequate supply (Verme and Johnston 1986), and seedling establishment increases in areas with greater seed input (Rooney et al. 2002).

The exclosure experiment has confirmed that browsing can limit cedar regeneration abundance (Figure 3). The data suggest that browsing impact differs between years. According to Cornett et al. (2000), animal browsing is another factor diminishing the survival rate of cedar regeneration. Cedar is browsed not only by deer, but also by hare under some conditions (Grigal and Ohmann 1975). Other rodents eat cedar seeds and seedlings (Johnston 1990). However, moose browsing on cedar seedlings has not previously been documented. We have not yet determined which animal browsed the cedar in the present study, but further

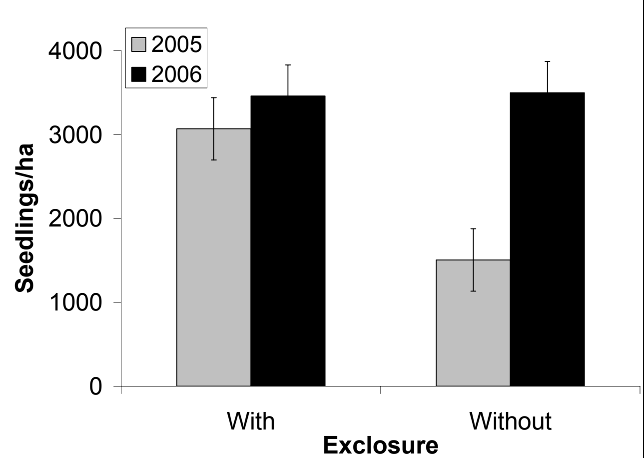

Figure 3. Mean abundance of cedar regeneration per hectare with and without animal exclosures (p=0.012).

analyses of the predation experiment will clarify this fact. When seedling browsing and seed predation are problematic, Raymond et al. (2003) and Cornett et al. (2000) suggest seeding at higher densities than would occur naturally to compensate heavy losses.

Over three years of planted cedar sapling growth monitoring, mean heights were respectively 410.6 cm, 464.4 cm, and 559.0 cm. Mean cedar height decreased in the control during the second year (Figure 4), likely due to mortality and hare and moose browsing. The height increment has been highest in gaps, because abundant light is necessary to continue cedar saplings development (Johnston 1990). This confirms previous observation of Logan (1969) that cedar was heaviest in gaps, because of its prolific branching in full light. A light intensity of 50% is better for height growth and root development (Logan 1969). In addition, time increases differences between treatments (Figure 4). In 2005, there was no significant difference between S25 and S50, but by the third year of growth monitoring, saplings were 18.6 cm taller in S50 than in S25.

Conclusion

We found three factors influencing cedar regeneration three years after cover reduction treatments. First, light level controls establishment, survival and growth of regeneration; harvesting more than 50% of the basal area resulted in less cedar establishment and survival than control and single-tree selection, but sapling height growth is proportional to light intensity. Second, natural seed rain after harvesting may be inadequate to ensure a cedar component, but artificial seeding on disturbed seedbed enhances cedar abundance for all treatments. Finally, animal predation and browsing can decrease the abundance of cedar regeneration on certain circumstances, but more analyses are necessary.

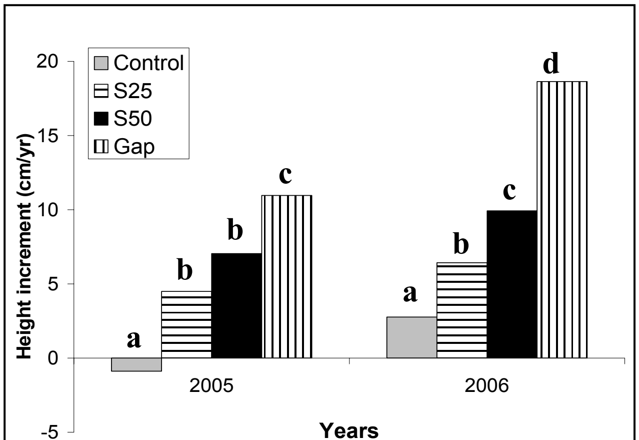

Figure 4. Mean annual height increment (cm) of planted cedar saplings in control and all canopy reduction treatments; different letters in the same year show significant differences (α=0.05).

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Theme: Silviculture

Using RADARSAT-1 and RADARSAT-2 images for forestry applications

Leblon, Brigitte[1]

Remote sensing has been used for a long time in forestry, going from the use of aerial photographs to the use of optical satellite images, like LANDSAT and thermal infrared images, like NOAA-AVHRR. However, all these remote sensing products have the main disadvantage of having a limited acquisition possibility during cloudy days as their acquisition depends on solar illumination. Such a limitation does not exist for radar (SAR) satellite images because SAR sensors send their own incident radiation, independently of solar illumination. The paper presents various applications of radar remote sensing in forestry, mainly based on the Canadian SAR sensor, RADARSAT-1, which has a wavelength of 5.3 cm and a HH polarization. They include mapping of forest disturbances (clearcuts or fire scars), wetlands, forest species, and fuel moisture. Compared with single-polarization SAR sensors like RADARSAT-1, the new Canadian SAR satellite, RADARSAT-2, will allow the acquisition of polarimetric SAR images in the HH, HV, VH and VV polarizations. These images provide much more information because they make it possible to construct the complete scattering matrix of nine independent elements. Airborne polarimetric images were already used to estimate the various scatterings from a boreal forest, to improve the classification accuracy over maritime pine forests and over boreal forests and to estimate moisture content over boreal jack pine forests. Advantages and disadvantages of both SAR sensors will also be discussed.

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Theme: Forest management, operations and engineering

A decision algorithm for determining safe clearing limits for the construction of skid roads

LeDoux, Chris[1]

Abstract

The majority of the timber harvested in the United States is extracted by ground-based skidders and crawler/dozer systems. Ground-based systems generally require a primary transportation network (a network of skid trails/roads) throughout the area being harvested. Logs are skidded or dragged along these skid roads/trails as they are transported from where they were cut to landings where they are loaded onto trucks for transportation to processing plants (sawmills, paper mills, OSB plants, veneer mills, etc.). The degree of construction/excavation required on these skid roads/trails varies with terrain steepness and the size of machines that will use them and the size of logs being transported. The excavation/construction of these skid roads/trails can create certain hazards that if not dealt with or eliminated can damage property or threaten human lives. For example, in the White .vs. Wenturine Brothers Lumber, Inc., ICI Explosives, USA and American Forestry Consultants .vs. John Bouch case, skid road excavation undercut the lateral support of a tree that was left on a vertical cut bank. The tree later fell on a logger severely injuring the logger. In this article we briefly review skid road/trail construction methods, review safety regulations, and provide a decision algorithm for determining practical and safe clearing limits/guidelines for the construction of skid roads.

Introduction

Society is increasingly demanding more of the nation's forests with respect to wood products (veneer, sawlogs, pulpwood, fuelwood, etc.) and recreational opportunities (hiking, biking, horseback riding, snowmobiling, etc.). Increased access to and use of our forest resources requires a network of haul roads and skid roads/trails (Skelton 1949; Meyer 1970). Haul roads generally are permanent and well designed, and receive heavy vehicle use. Most skid roads/trails are temporary and often poorly designed, but vehicle traffic on these roads is light once harvested timber has been extracted. However, skid roads/trails (hereafter called trails) continue to be used for recreation activities such as hiking, hunting, and horseback riding even after many of them have been gated or otherwise blocked off.

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Most of the timber harvested in the United States is extracted by ground-based skidders and crawler/dozer systems. Grounded-based systems require a primary transportation network throughout the area being harvested (Wackerman et al. 1966; Pearce and Stenzel 1972). Following cutting, logs are skidded or dragged along these trails to the landing, where they are loaded onto trucks for transport to sawmills, paper mills, OSB plants, veneer mills, etc. (Conway 1976). The degree of construction/excavation required on these trails varies with the steepness of the terrain and the size of logs/logging vehicles (Wenger 1984). Excavation/construction can create certain hazards that if not eliminated can damage property and threaten human lives. In one incident that led to a court case (Melvin Willard White vs. Wenturine Brothers Lumber, Inc., ICI Explosives, U.S.A., and American Forestry Consultants, vs. John Bouch Logging, In the Court of Common Pleas of Westmoreland County, Pennsylvania, Civil Division No. G.D. 382-2000, 2003), excavation undercut the lateral support of a tree that was left on a vertical (vs. backsloped) cutbank. The tree later fell, severely injuring a logger. In this article we briefly review current trail construction methods, review safety regulations, and provide an algorithm for determining practical clearing limits/safety guidelines for trail construction.

Materials and methods

The construction of trails on flat or gentle terrain requires little excavation. Trees, vegetation, or other obstacles are simply pushed out of the way with a bulldozer to create a trail that can be negotiated with a skidder, crawler tractor, farm tractor, or forwarder. Construction on steep terrain requires considerable excavation and movement of earth. On such terrain, the trail must be carved out of the hillside, which moves or otherwise displaces obstacles such as soil, rocks, and trees. Most of this material is deposited on the downhill side of the road and the bulk sometimes is buried in the fill or used as a barrier to hold the fill in place (Wenger 1984).

The following variables should be considered in judging whether to remove a tree or other obstacle from a cutbank during or following trail excavation (LeDoux 2004a, LeDoux 2004b):

- Sideslope (%). Steep slopes (≥ 25%) are unstable and require more excavation on the uphill side and more fill on the downhill side. Very steep slopes require full bench roads.
- Soil, solid/loose. Loose rock, etc. moves easily.
- Distance from cutbank edge. The closer the tree/obstacle is to the cut edge, the more likely it will fall.
- Moisture/aspect. Once soils reach the plastic limit, they are nearly liquid in consistency.
- Size of tree/obstacle. The larger the tree/obstacle, the greater amount of mass is on the cutbank.
- Undercut roots/soil. These remove a tree’s attachment to the ground, undermining stability.
- Species of tree. Certain species are shallow rooted while others have deep taproots.
- Tree health/vigor. A sound, healthy tree with a full crown always has a strong anchoring mechanism (root system).
- Clearing limits. Should be set and maintained where applicable.

These variables were used to construct a decision/flow diagram algorithm that can be used to help loggers/managers and folks involved in skid trail construction to define safe clearing limits. A dozer operator could use this algorithm to quickly decide if a potentially hazardous tree should be felled, felled and grubbed out, or left alone during the construction process. The decision algorithm could also be used post construction to decide on potential hazard trees/obstacles that result from everyday operating conditions and on the job shifting changes.

Results

Figure 1 integrates the above variables and is useful for setting practical and safe clearing limits for trail construction as it addresses decisions on removing trees within and adjacent to the cross section for trails with vertical or backsloped cutbanks.

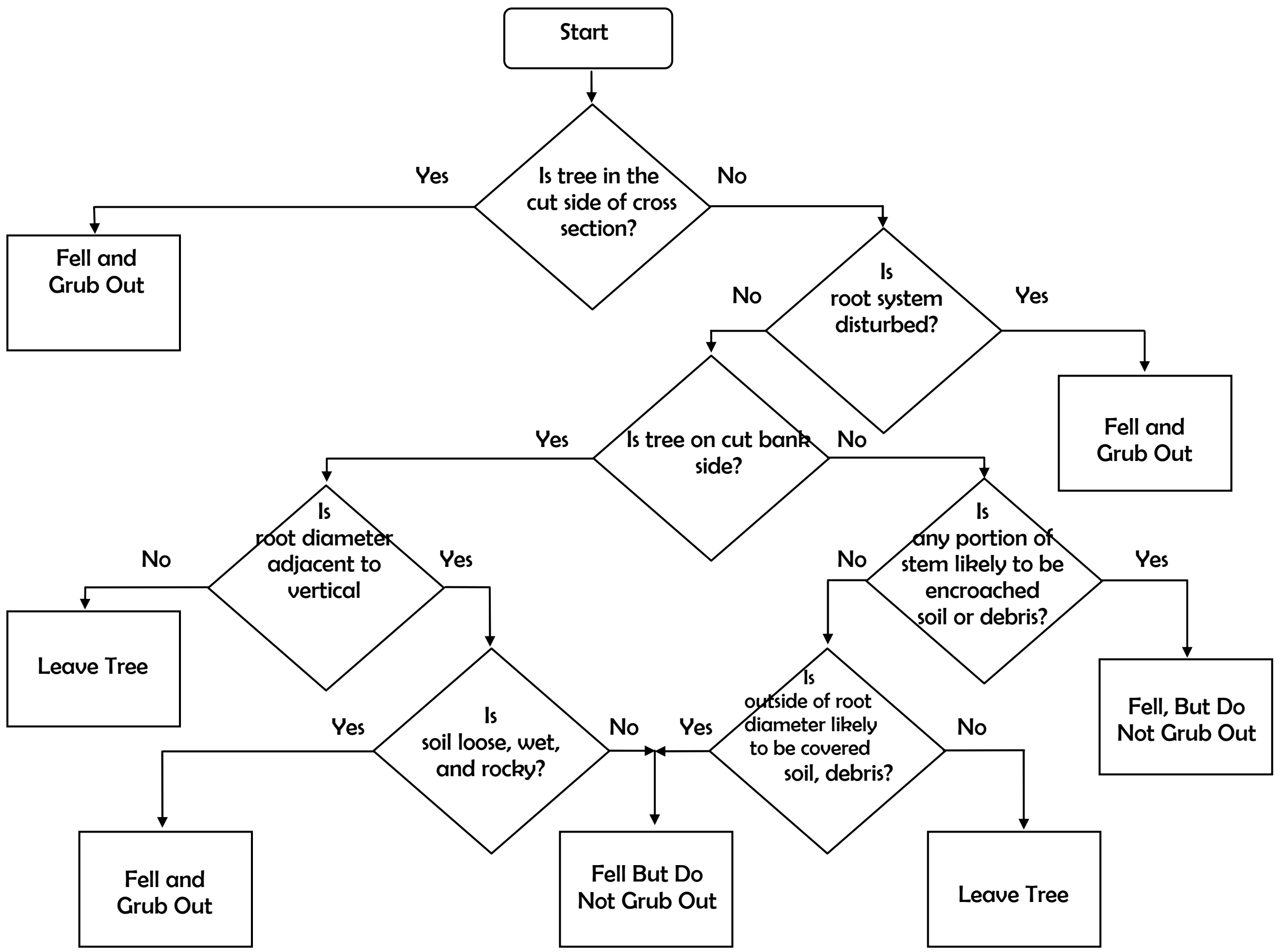

Figure 1. Decision chart for determining practical and safe clearing limits for skid road/trails with backsloped or vertical cutbanks and fill slopes.

Discussion

Few guidelines on clearing limits for forest haul roads (Anonymous 1983; Wenger 1984; OSHA 2000, 2001) are applicable to trails. The general recommendation is that "all snags, danger trees, loose rocks, stumps or other unstable material shall be removed or cleared for a safe distance back from roadsides or roadside banks when they present a hazard to users of roadways", and that "brush foliage or debris which would obstruct the view of a vehicle operator on roadway intersections or on sharp curves shall be cleared and all possible precautions shall be taken to relieve the hazard of such conditions" (Anonymous 1983).

Conclusion

The construction/excavation of skid roads/trails creates certain safety hazards that can be eliminated and/or mitigated by observing practical and safe clearing limits during and after trail construction/excavation. The decision chart included in this article should be helpful in determining guidelines that will result in a safer workplace. On a practical level, if there are doubts about a tree's stability, that tree should be removed. It is beyond the scope and space allowed for this report to detail the development and theory behind this decision algorithm. However, for a more detailed explanation of the development and examples of use of the decision algorithm see (LeDoux 2004a).

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Theme: Forest management, operations and engineering

Irregular Shelterwood system

Lessard, Guy[1] and Donald Blouin[2]

Biodiversity conservation in mixedwood and hardwood forests requires the development and implementation of more diversified silvicultural approaches. To manage stands with species of different longevity and variable tolerance to shadow (e.g. sugar maple, yellow birch and spruces), irregular shelterwood appears to be one of the most relevant methods. Part of the irregular high-forest system, this regeneration process includes a group of free treatments that represent a compromise between clear cutting, uniform shelterwood and selective cutting to ensure regeneration in a non-homogeneous manner. The establishment of regeneration is longer than in shelterwood cutting and can extend over 1/5 to 1/2 of the revolution. During this period, the stand will not develop into a balanced inverse J structure and maintaining a permanent canopy is not the main objective. The main objective is the creation of stands using natural regeneration. Two forms are presently being investigated on a scientific basis: uniform irregular shelterwood (many cohorts superimposed) and group irregular shelterwood (many cohorts juxtaposed). While they have been known and put into practice for more than a century by European foresters, the interventions' specifications in regard to Quebec's ecological and operational conditions are still under development, mainly for the following aspects: identification of stand characteristics that best suit irregular shelterwood cutting, identification of the most suitable specifications, establishment of an action plan, assessment of costs and productivity according to the specifications retained, and control of quality and yield.

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Theme: Silviculture

Uniform selection cutting issues in Quebec

Lessard, Guy[1] and François Laliberté[2]

The silviculture of mixed and deciduous forests in Quebec has been largely discussed over the last few years. The definition of what can be considered as uniform selection cutting and what the options are when it is not applicable are part of an important debate. In many cases, uniform selection cutting is considered the only way to maintain forest cover and yield. Considering the inherent difficulties in uniform selection cutting, new options are proposed, but most of them focus on short-term supply and profitability. Although important, these preoccupations should not replace silvicultural diagnostics, stand education and the development of improved stand value. A choice must be made in an objective, rigorous and organized manner (problem solving method). The solution probably lies in the use of a variety of silvicultural systems and treatments that aim at regulating product flow and build a high-value forest capital. Making compromises is required but, more importantly, a change in attitude towards the engineering work needed for the conception of innovative silvicultural prescriptions, mainly at the level of the intervention specification, is mandatory. Major investments will be needed to rehabilitate forests and their optimization will necessarily require economic analyses made with appropriate tools.

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Theme: Silviculture

Evaluation of three methods for predicting diameter distributions of black spruce (*Picea mariana*) plantations in central Canada

Liu, Chuangmin[1,2], S.Y. Zhang[1,2] and Peter F. Newton[3]

The direct parameter prediction method (PPM), moment-based parameter recovery method (PRM), and percentile-based parameter recovery method (PCT) for estimating the parameters of the 3-parameter Weibull probability density function (pdf) were evaluated for goodness of suitability in predicting the diameter distribution of unthinned black spruce (*Picea mariana* (Mill.) B.S.P.) plantations. Employing diameter frequency data derived from 267 permanent sample plots situated throughout central Canada, fit (n=214) and validation (n=53) data sets were created. Using stepwise regression analyses in combination with seemingly unrelated regression techniques, the three methods were calibrated using commonly measured prediction variables (stand age, dominant height, site index, and stand density). Results indicated that all three methods were good at predicting the diameter frequency distributions within the sample stands. Of the three methods assessed, however, the PCT was considered the most suitable for describing unimodal diameter distributions via the 3-parameter Weibull pdf within unthinned black spruce plantations. Further research is underway to model diameter distributions for three types of jack pine stands (unthinned natural stands, unthinned plantations, thinned stands).

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Theme: Modeling, growth and yield

Spectral analysis to explore feedback effects of ericaceous shrubs on soil properties of wildfire- and harvest-origin boreal sites

Lorente, Miren[1], William F.J. Parsons[2], Catherine Périé[3] and Alison D. Munson[1]

Wildfire disturbance is being replaced by harvesting in black spruce-feathermoss forests of Quebec. After harvest disturbance, these sites can be subject to invasion of ericad species that reduce the growth and regeneration of black spruce. Wildfire or harvest disturbance may leave a different biological heritage of ericad presence on the site, and the resulting patterns may have important feedbacks to the ecosystem. We explored these patterns and potential feedback on two fire-origin and two harvested stands in central Quebec. Along 50 m transects, we measured ericad characteristics (cover, biomass), soil microclimate (Tº, moisture, PAR), soil quality indicators (N, C, N mineralization), microtopography and tree characteristics (density, diameter, height). Our objectives were to characterize spatial patterns of these variables, and to evaluate the contribution of ericads to explain the spatial patterns, using spectral analysis. Ericad cover, temperature, PAR, tree height and microtopography presented complex spatial patterns on both old disturbances, while total N, C:N, tree diameter and density presented patterns only on the old burn site. The scales of spatial dependency were greater in the burn site compared with the harvest site. Ultimately, we found that these variables were strongly correlated with ericad cover as a function of spatial scale.

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Theme: Forest ecosystems

Impact of experimental uneven-aged silvicultural systems on the structure of boreal spruce-fir stands of Eastern Canada

Lussier, Jean-Martin[1], Philippe Meek[2], Jean-Claude Ruel[3] and Vincent Roy[2,3]

Uneven-aged stands are an important component of primary forests of the most eastern part of the Canadian boreal region, due to very long forest fire cycles and small-scale disturbances. Current forestry practices, based on clearcutting with protection of the existing advanced growth, are inadequate to maintain the essential ecological attributes of the primary forest (i.e. continuous forest cover, dominance of shade-tolerant softwood, production of large woody debris and presence of "large" trees). In 2004-2005, two new silvicultural systems were tested and compared with existing practices (clearcutting with protection of advanced regeneration and cutting with protection of small-diameter merchantable trees) in four blocks, including five 20-ha experimental units. Systems were designed for mechanized harvest. One system is based on the single-tree selection system, while the other follows an irregular strip shelterwood approach. In all cases, silvicultural prescriptions were formulated to take into account the heterogeneous horizontal structure of the stands. Tree selection was entrusted to the harvester operator. The immediate impact of the two treatments on stand structure and productivity will be presented.

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Theme: Silviculture

The multiple-treatment approach: An innovative partial cutting system

Meek, Philippe[1] and Jean-Martin Lussier[2]

The Forest Engineering Research Institute of Canada (FERIC) and the Canadian Forest Service (CFS) developed a very efficient approach to implement partial cutting where the stand structure is highly variable. The approach allows cost reduction for shelterwood systems or selection cut by entrusting the machine operator with the selection of the appropriate set of guidelines as a function of local stand conditions. A pre-treatment survey is required to assess the different stand types and the guidelines are established in accordance with the treatment objectives for each stand type. During the partial cut operation, the feller-buncher or the harvester operator identifies the surrounding stand type and selects the appropriate operating guidelines. These include trail establishment patterns and tree selection criteria. The multiple-treatment approach was tested in three different cases involving the first entry of a shelterwood system and the development of a selection cut system in irregular softwood stands. With this approach, the implementation of the treatment had a low cost and it made it possible to reach the treatment objectives. The operator's selection ability and performance was demonstrated satisfactorily in each trial. Specific sampling procedure before and after the treatment can provide sufficient information to monitor and control the process. The multiple-treatment approach is a robust tool to facilitate the development of partial cutting guidelines that meet silvicultural and operational objectives in a variety of stand conditions.

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Theme: Forest management, operations and engineering

Forest inventory maps: A useful tool for a wetland habitat classification and regionalization in Quebec's forests

Ménard, Sylvain[1,2], Marcel Darveau[2] and Louis Imbeau[4]

Abstract

Even if we have acquired a good knowledge of wetlands' ecology and classification, quantification of the abundance of wetland types and delineation of homogeneous regions in terms of wetland habitats are still lacking in forest dominated landscapes. The most limiting factor for coarse-scale studies of wetlands is clearly the absence of a precise and reliable wetland spatial database available at low costs. Our objective is thus to develop such a tool based on forest inventory maps. A distribution study of wetlands was conducted on a 540 000 km^2 area located in boreal Quebec. A total of 448 numerical forest inventory map leaflets systematically distributed were chosen, covering 20% of the study area. Using GIS rules and queries, it was possible to discriminate several types of deepwater and wetland habitats of faunal interest according to a classification system inspired from Rempel's (1997) wetland habitat classification for boreal forest waterfowl and adapted by Breton (2005) (Ménard *et al*. 2006). Results evidenced the spatial heterogeneity, richness and complexity of the wetlands found in our study area. On average, wetlands and deepwater occupy respectively 11.7 % and 10.3 % of the study area but these proportions showed considerable spatial variation. We conclude that forest inventory maps can be used to quantify the area of wetland habitats and to define homogeneous regions in this regard, and therefore provide a functional tool for coarse-scale wetland management and protection.

Introduction

Because large portions of forested landscapes are rather isolated from inhabited regions, they are not submitted to the pressures of urbanisation and agriculture, and many people (including conservation organisations) tend to think that they are implicitly protected. However, it is difficult to determine the scope of the global impact of forestry, mining, hydroelectricity, the gaz and oil industry and even recreotourism on wildlife and their habitat. If foresters and biologists

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want to provide management guidelines in the eastern forest, they need to fill knowledge gaps relative to wetland classification and its importance to wildlife. Even if we have acquired a good knowledge of the ecology and classification of wetlands, a quantification and regionalisation of the abundance of wetland habitats are still lacking in boreal Quebec. The most limiting factor for coarse-scale studies of wetlands in Quebec's forests is clearly the absence of a precise and reliable wetland spatial database available at low costs.

Methods

Because forest inventory maps are not able to accommodate any of the existing wetland classification systems, wetland habitats have been mapped using a functional system that we have especially developed for this purpose (Ménard *et al.* 2006). The system is inspired from Rempel's (1997) wetland habitat classification for boreal forest waterfowl which was developed for aerial photography. Breton et al. (2005) adapted and automated the system so it could be used with forest inventory maps. We started out from this system, refining and improving it. Our classification system has two hierarchical levels (Tab. 1). At the first level, wetlands are grouped into four classes: 1) Aquatic, 2) Shoreline, 3) Swamp (five sub-classes according to trophic level, soil and vegetation), 4) "Bare wetland", corresponding to commercially unproductive wetlands (bogs, fens, marshes, etc.). Two sub-classes have been added: 1) isolated wetland and 2) wetland complex. This subclass proved to be necessary when preliminary results showed the presence of large polygons (> 8,000 ha) in which several types of wetlands and forest stands were embedded.

At the second level, the Shoreline and Bare wetland classes are subdivided according to the hydrological system that it is in contact with. Those systems (reservoir, lake, pond, isolated pond, river) are discriminated by their size, water level variation and the presence / absence of water level regulation. For habitats in contact with more than one hydrological system, hierarchy has been defined as follows: Reservoir > Lake > Pond > River > Isolated pond.

In order to map wetland habitats, we have acquired 448 forest inventory map leaflets (in numerical form) of the Quebec Ministry of Natural Resources and Wildlife (3rd edition; scale 1:20,000; 14 km x 18 km = 252 km² per leaflet). Our design overlays the design of a grid of 156 waterfowl survey plots distributed in Quebec's boreal forest by the Canadian Wildlife Service (CWS) in the 1990s, allowing us to investigate waterfowl –wetland habitat relationships in a concomitant project. The maps cover 20 % of the 540,000 km2 study area bounded in the north by the 51°15' N and in the south by the Saint-Lawrence lowlands (Fig. 1).

The forest inventory map has been chosen because it is an easy to use database that covers almost entirely the forested portion of the province. It is also a well known tool that is already used not only by forest managers, but also by biologists and land use planners. In numerical form, it contains a lot of information pertaining to wetlands and deepwater habitats. Hydrography (surfaces and linear features) is defined by an attribute (lake, river, reservoir, perennial and ephemeral streams) and the Quebec Forest Inventory Service (SIEF) has mapped unproductive wetlands (wetlands with no timber production: alder swamps, flooded forests and "bare wetlands") and determined ecological types for productive stands, characterising potential vegetation and station (Grondin et al. 2003). The database allows us to identify wetlands as small as 1 ha for unproductive wetlands and 8 ha for productive stands.

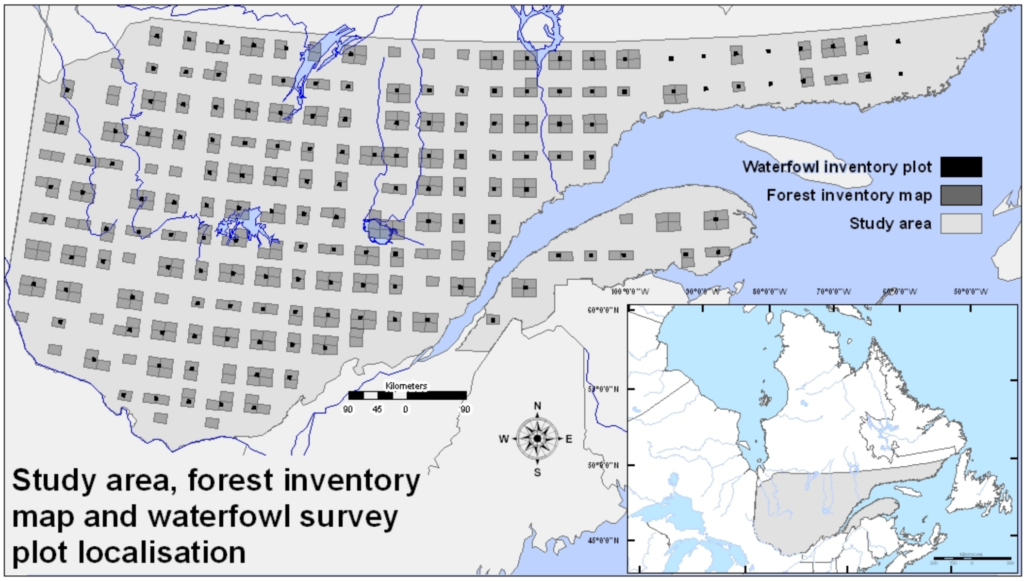

Figure 2: Study area (gray) and acquired forest inventory maps (dark gray).

Results and discussion

Results evidenced the spatial heterogeneity, richness and complexity of the wetlands of forested Quebec. Wetlands and deepwater occupy respectively 11.7 % and 10.3 % of the study area (Tab. 1) and vary considerably across the region (Fig. 2). Considering a sampling effort of about 20 %, these results are in concordance with the National Wetland Working Group's (NWWG 1988) estimation which is of 9 % wetland coverage.

Table 1: Wetland habitat classification**.** The land cover proportion is calculated over the 448 forest inventory maps (130 000 km^2). The estimated km^2 is for the total study area.

Class	Subclass	System	Type	Land cover (%)*	Estimated $km^{2\dagger}$
Aquatic		Reservoir	AqD	2.7	14,310
		Lake	AqL	6.1	32,668
		Pond	AqP	0.8	4,173
		Isolated pond	AqI	0.1	385
		River bed	AqR	0.6	3,345
	Total			**10.27**	**54,882**
Shoreline		Reservoir	ShD	76*	43,636†
		Lake	ShL	83.3	230,398
		Pond	ShP	59.1	10,733
		Isolated pond	ShI	64.7	104,665
		River	ShR	73.1	682,197
	Total			**74.06**	**1,071,631**
Swamp	Alder		SwA	0.9	4,820
	Poor forested		SwP	1	5,100
	Rich forested		SwR	1.2	6,551
	Forested bog		SwB	2.1	11,132
	Flooded		SwF	0.3	1,345
	Total			**5.42**	**28,950**
Bare wetland	Complex		BwC	1.5	8,263
	Isolated		BwX	0.6	3,471
		Reservoir	BwD	0.1	336
		Lake	BwL	1.1	5,859
		Pond	BwP	1.1	5,851
		Isolated pond	BwI	0.03	208
		River	BwR	1.8	9,589
	Total			**6.28**	**33,579**

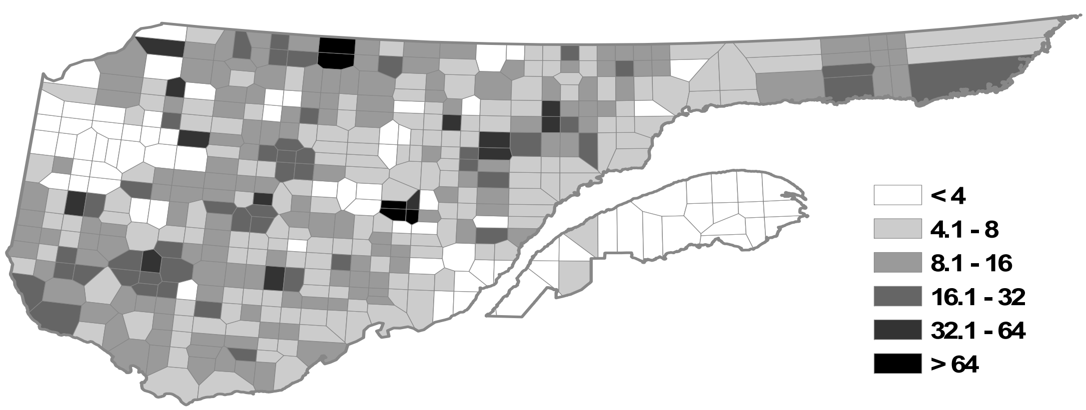

Figure 3 : Deepwater habitat (Aquatic class) land coverage for each map**.** Tessellation was used to fill the gaps between the maps

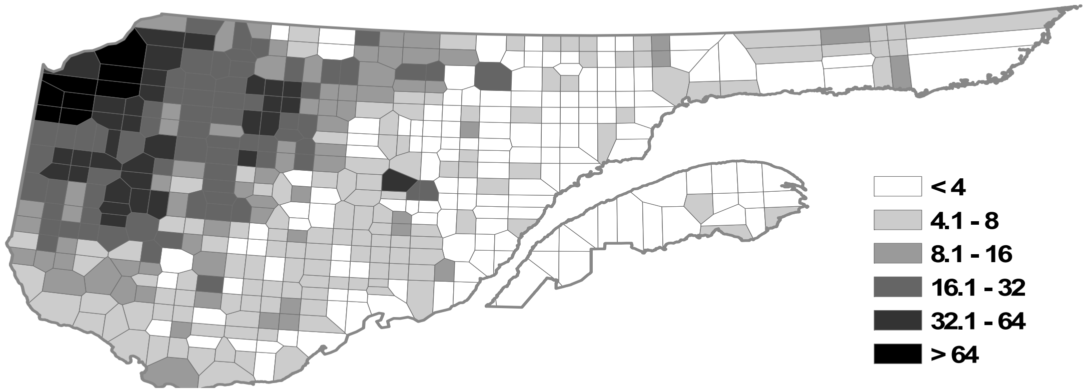

Figure 4: Wetland habitat (Bare wetland and Swamp class) land coverage for each map**.**

Conclusion

We believe that our classification system will add much value to a tool that is already valuable for other purposes. It's a simple, efficient tool, available at low cost, which we hope will answer the needs of several users. The wetland habitat distribution study results will be used to create homogenous regions in terms of wetland habitats associations and proportions. This regionalisation should be quite useful for research, land use planning, and modelling. Furthermore, because Quebec's forest inventory maps are revised every 10 years, it will be possible to refine the classification as the database becomes more precise.

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Theme: Forest ecosystems

Comparative analysis of forest tenure types: Effects on forest structure

Morin, Patrick[1], Luc Sirois[2] and Luc Bouthillier[3]

Forests are increasingly being disturbed by timber harvesting activities, while the population is requesting a more balanced resource management between environmental, social and economic values. Forest tenure can be divided according to two main ownership types, private and public. Historically, forests around the world were almost exclusively under public tenure. Today, 81% of the world's forests are under public tenure, while an increasing portion (19%) are private. This trend, in a context where examples of natural resource overexploitation are multiplying, requires some reflection about the potential effects of these changes in management types. This study aims to compare and contrast the private and public forests of the Bas-Saint-Laurent region, which occupy an equal share of the same ecological region. We will present the first aspect of this comparison, which is at the environmental level. Using watersheds that are partly private and public, we will verify how the structure of forest ecosystems is affected by the tenure. This project also aims to integrate silvicultural approaches and socio-economic indicators of sustainable forest development to better understand the differences between the types of tenure. Ultimately, all three aspects will be integrated into a SELES-based model in order to understand the social, environmental and economic implications of each type of tenure.

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Theme: Forest management, operations and engineering

Growth response and mortality of *Thuja occidentalis* L. after partial cuts in mixedwood stands of Quebec and Maine

Morissette, Sabrina[1], Jean-Claude Ruel[1] and Jean-Martin Lussier[2]

In the province of Quebec (Canada), an important part of the supply of *Thuja occidentalis* L. comes from mixedwood stands that are often harvested by the selection system. However, little is known about the sustainability of this practice for cedar. Furthermore, existing knowledge on cedar growth and mortality dynamics is sparse. The general objective of this retrospective project is to measure and describe residual tree responses to partial cutting. The ultimate objective is to create empirical models for cedar diameter growth and mortality. An analysis of the cedar long-term radial growth pattern will also be completed in order to evaluate the impact of partial cuts on this species. The field work was conducted during summer 2005 in western Quebec. Eight stands partially cut between 1971 and 1983 were then sampled. Over 2200 partial cores were collected, including 500 cedars. Over 400 discs of dead trees were also collected. Additionally, four stands located in Maine (Penobscot Experimental Forest) were chosen for comparison with western Quebec stands. Growth measurements were completed in May 2006. Results of these measurements, along with cedar growth and mortality models, will be shown during the oral presentation.

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Theme: Modelling, growth and yield

Sustained yield management on eastern US non-industrial private forestland: Understanding the role of owners, their forests and regional socioeconomic context

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The management of non-industrial private forestland (NIPF), or private forests owned by individuals or corporations other than the forest industry, is often characterized as an individualistic process driven by owner preference. Accurate characterizations, however, also hinge on understanding how these individual preferences are influenced by social and biophysical context. To better understand these influences, we studied the interaction of individual owners, their forests, and regional socioeconomic factors during timber harvests on US NIPF. We hypothesized that socioeconomic factors and forested conditions significantly influence linear, individualistic models used to measure sustained yield forestry implementation. An oral survey of NIPF owners, a field evaluation of their harvested forest, and secondary data analysis of regional socioeconomic aspects were combined for this study. The research was conducted on New York and Mississippi NIPF harvested within the past 5 years. The oral survey used Rogers' and Nowak's diffusion of innovation models to measure an owner's pre-harvest decision-making and employed Ajzen's theory of planned behavior model to measure post-harvest intentions. The field survey evaluated post-harvest conditions and collected data to estimate pre-harvest attributes. These results are placed in sequential order and juxtaposed with secondary socioeconomic data to improve our understanding of the interrelationship between owner, society, and forest.

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Theme: Forest management, operations and engineering

New thoughts from old plots:
Estimating carbon stocks in Canada's oldest permanent plots

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The Petawawa Research Forest is the site of the first permanent sampling plots in Canada, established in 1918 after a requirement set out in 1916 by the Forestry Branch Advisory Council. Permanent sampling plots (PSP) 1 and 2 were laid out in a fire-origin mixed stand of red and white pine, birch, aspen and spruce. PSP 1 was subsequently thinned on a 10-yr cycle starting in 1918, while PSP 2 was a control with no intervention. Individual trees were tagged, numbered, mapped and re-measured every 5, and then 10 years (last measurement in 2005). We combined re-measurement in 2005 with an assessment of carbon (C) stocks in the soil and aboveground biomass. In general, a more important litter layer and woody debris were measured in the control plot (PSP 2) compared with the plot that was thinned (PSP 1). Although concentrations of C were similar in F and Ah horizons in the two plots, the F horizon accumulated in the control plot was more than twice the depth of the F horizon in the thinned plot. The Ah horizon in the control also tended to be deeper. Accumulations of C in the 0-15 cm and 15-30 cm mineral layers are also reported.

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Theme: Forest ecosystems

Mapping of upland forest sensititivity to acid deposition in Eastern Canada

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Critical loads (CL) were estimated for upland forests in Eastern Canada using the steady-state Simple Mass Balance (SMB) Model. An important contribution of this first large-scale CL mapping (area: 1,789,420 km^2) was the use of terrestrial soil landscape or ecozone units. In this project, CL estimates and steady-state exceedance values considered that forests are in steady-state, i.e. they did not include the effect of forest fire and forest harvesting. The area-weighted median CL for each province varied between 519 (Quebec) and 2063 eq ha^{-1}y^{-1} (Prince Edward Island), with a median CL value for Eastern Canada of 559 eq ha^{-1}y^{-1}. It is estimated that approximately 52% of the mapped area was exceeded by the 1994–1998 average total (wet + dry) atmospheric sulphur and nitrogen deposition. Greatest exceedances occurred on the Canadian Boreal Shield in Ontario and Quebec and in southern Nova Scotia, due to low CL and high loads of acid deposition. Evidence is accumulating about the relationship between CL excess and poorer forest growth and health.

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Theme: Tree physiology, carbon and nutrient cycles and genetics

Silvicultural response of two New Brunswick spruce plantations to mid-rotation commercial thinning

Pelletier, Gaétan[1] and Doug G. Pitt[2]

Two J.D Irving Limited trials, established in 19- and 24-year-old white spruce plantations in 1987, compare the outcomes of single-, delayed-, and double-entry commercial thinning. All of the thinning strategies satisfied the objectives of focusing volume growth on a reduced number of stems and making merchantable volume available during the rotation. Through to age 36 or 40, there were no overall gross merchantable volume gains or losses associated with any of the thinning strategies tested. Single-entry thinning allowed 30 to 50 m^3/ha to be harvested between ages 19 and 24, increasing age 36 to 40 quadratic mean diameter and merchantable volume per stem by more than 10% and 24%, respectively, over unthinned stands. Double-entry strategies that removed an additional 48 to 64 m^3/ha between ages 30 and 32 increased these diameter and volume gains to more than 25% and 71%. Delayed-entry removals averaged more than twice the merchantable volume of the single-entry removals and virtually the same total volume as the double-entry removals, increasing age 36 to 40 stem diameter and volume by more than 18% and 49%, respectively. As such, this approach may offer economic advantages over the other two. Only marginal differences were observed between the tree-selection strategies tested.

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Theme: Silviculture

Long-term response of balsam fir to precommercial thinning in northwestern New Brunswick

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The Green River Spacing Trials, established by Dr. Gordon Baskerville in 1959-61, now offer more than 40 years of growth response data with which to weigh the costs and benefits of precommercial thinning. Three nominal spacings (4' (1.2 m), 6' (1.8 m), and 8' (2.4 m)) and an unthinned control were applied in a randomized complete block design with 6 replicates to balsam fir/spruce regeneration averaging 16 years of age, 8 years after harvest. While thinning had a minimal effect on gross total volume production over the observation period, actual spacings between 2.1 and 2.5 m produced a 21% gain in gross merchantable volume over unthinned stands and an average of 360 m^3/ha (based on an 8 cm minimum top diameter). The same spacings increased quadratic mean diameter from 18 cm in unthinned stands to 21 and 23 cm, respectively, translating to increases in stem volume of 33 and 62%, and dramatically reducing the age at which thinned stands meet a specified minimum requirement for merchantability or habitat. Thinning intensity, however, directly influenced stem height:diameter ratio and taper, potentially offsetting some of the value gains associated with larger piece sizes.

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Theme: Silviculture

A test of the Forest Vegetation Simulator - Northeastern US (FVS-NE) for simulating long-term growth dynamics following partial-cutting in the Acadian forest type

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Abstract

Researchers, practitioners and policymakers increasingly rely on model based predictions of forest growth for long-term planning. The Forest Vegetation Simulator (FVS), developed and supported by the USDA Forest Service, is perhaps the most widely used forest dynamics model in the US. Regionally parameterized variants have been developed for the major forested regions (e.g. 'FVS-NE' for the Northeastern US). This paper compares model predictions with long-term observations from an independent data source documenting 25-30 yrs of stand dynamics following repeated partial cutting at the Penobscot Experimental Forest in central Maine. Our results indicate a tendency for the current model to overestimate growth and underestimate mortality. These trends manifest in as much as a 20-40% difference in predicted vs. observed live basal area (BA) by the end of the simulation period for certain treatments. The ability of FVS-NE to forecast the dynamics of structural elements (i.e. BA growth by 10-cm diameter class) was similarly biased, with the growth and survival of small stems tending to be overly optimistic in these irregularly structured stands. Somesuggestions for how the developers might improve the performance of FVS-NE are outlined.

Introduction

Decision makers are increasingly confronted with information needs involving extended planning horizons when addressing contemporary forest resource issues (e.g. ecological restoration, climate change and carbon storage, etc.). The use of computer simulation models, which have proliferated in recent years, provides the only viable means for dealing with this level of complexity. Unfortunately, vigorous testing of the ability of existing forest dynamics models to accurately predict long-term change is rarely possible and seldom done.

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The Forest Vegetation Simulator (FVS), an empirically based growth and yield model developed and supported by the US Forest Service (Dixon 2006), is freely available and widely used throughout the US. FVS is unique among the various models that have been developed for this purpose in that it has a long and consistent history of refinement and user support. Regional variants of FVS have been developed for predicting forest dynamics within the different forest regions of the US, the Northeastern Variant (FVS-NE, formerly NE-TWIGS) applies to the 14 Northeastern States (Bush 1995).

Recent paradigm shifts in North American forestry (Kohm and Franklin 1997, Hunter 1999) have resulted in a transition towards multi-aged management promoting the creation of more irregularly structured stands. This is true in Maine, where a dramatic shift away from clearcutting has occurred over the past 15 years. While its developers contend that the FVS modeling framework is robust for predicting forest development in response to a wide range of management approaches (Hilt and Teck 1989), recognition of the complexity inherent in multi-aged systems calls for greater scrutiny of model outputs. To accomplish this we compared predictions from FVS-NE with long-term observations of forest development in response to repeated partial cutting at the Penobscot Experimental Forest (PEF) in central Maine.

Methods

The Dataset- The PEF is the location of a long-term silvicultural compartment study established as a collaborative effort between the USDA Forest Service and the forest industry in the early 1950s. The 1619-ha property is located in central Maine, USA (44°52'N, 68°38'W) within the Acadian Forest Region, characterized by a mixture of shade-tolerant northern conifers (most notably: red spruce (*Picea rubens*), balsam fir (*Abies balsamea*) and eastern hemlock (*Tsuga canadensis*) and faster growing hardwoods (primarily: red maple (*Acer rubrum*), paper birch (*Betula papyrifera*) and aspen (*Populus* spp.). Precipitation averages 106 cm annually and is evenly distributed throughout the growing season. Soils are of glacial till origin and tend to be somewhat poorly drained across the flat areas where the compartment study is located (we estimate the average site index at age 50 for balsam fir as 18 m).

The growth and development of individual trees in response to six partial-cutting treatments (2 reps/treat) has been documented at 5-yr intervals since the mid-1970s. Species, diameter at breast height (dbh, 1.4 m), and status (i.e. ingrowth/live/dead/harvested) were recorded at each inventory. Stems ≥11.5 cm dbh have consistently been tracked on 0.08 ha (5^{th} ac) plots, while smaller stems (1.3 to 11.4 cm dbh) were historically measured on nested 0.02 ha (20^{th} ac) circular plots. Ingrowth to the 1.3 cm dbh size class was assessed on the 0.02 ha plots. For a more detailed description of the PEF study system the reader is referred to Sendak et al. (2003).

The Model- All simulations were carried out using version 6.21, revision date: 07.05.06 of FVS-NE running through the Suppose interface (Crookston, 1997). Initial conditions on the 211 0.08-ha plots were projected from 25 to 30 yrs to match up with the most recent inventories in each compartment. Two model-run scenarios were compared to the observed data. In the first instance, site quality was characterized as SI=18 m for balsam fir (the most ubiquitous species) across all of the compartments. The other scenario involved using observed diameter increment over the initial 5-yr interval to calibrate the growth of the common species at the level of the individual plot (Dixon 2002).

Removals and ingrowth associated with the periodic harvests were included in the simulation runs. Because individual trees were followed over time we were able to cut specific trees that were removed in harvests and specify the ingrowth of regeneration at the appropriate time within the original tree lists. The process was automated through the use of FVS addfiles (i.e. *.kcp). Summary data was output via the Database Extension to FVS (Crookston et al.2006) to a linked database. Sprouting of certain hardwoods (e.g. red maple), the only automated form of regeneration supported in FVS-NE, was suppressed.

Model performance was assessed on the basis of comparisons between observed and predicted values for live and mortality basal area (BA, m^2/ha) over the length of simulation. Structural dynamics were further evaluated by comparing growth within 10-cm wide diameter classes. We chose BA as the response variable because it provides the most direct comparison with the original model (Hilt and Teck 1989).

Results and discussion

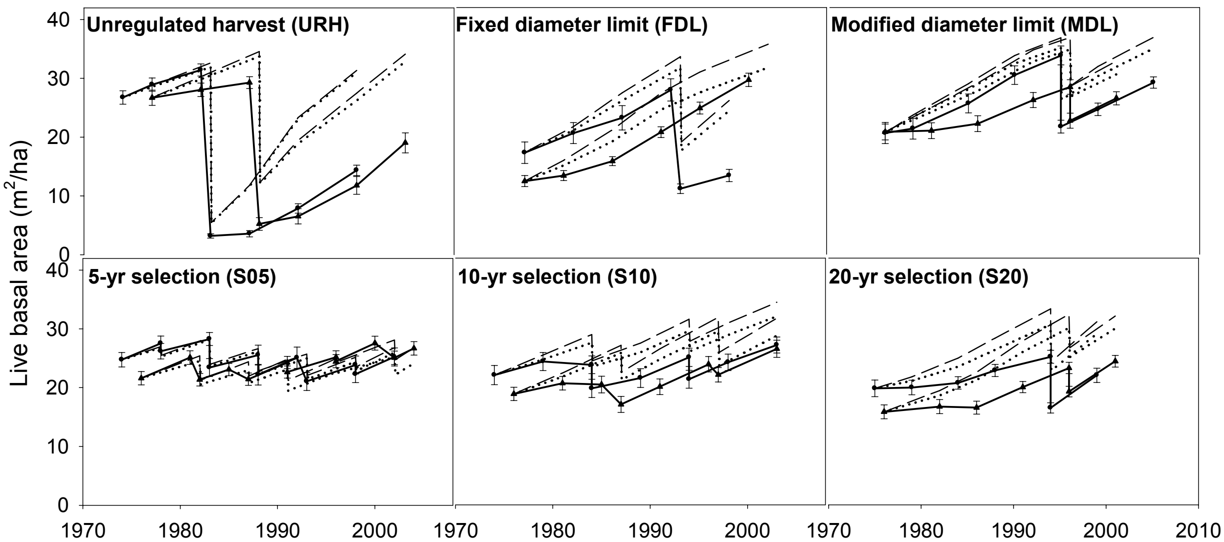
Notable differences among the six partial-cut treatments at the PEF included the number of harvests, residual stocking levels (BA), and the proportion of hardwood species (Table 1). In general, the more intensive selection treatments (S05, S10) have maintained higher residual stocking that has favored the shade-tolerant conifer component (BF/RS/EH). By contrast, the unregulated harvest treatment (URH) was cut heavily twice, has a relatively low residual stocking, and correspondingly higher hardwood component. An earlier assessment of the performance of NE-TWIGS relative to other available simulation models in the region indicated that it worked better in the hardwood forest types than for spruce-fir (Schuler et al. 1993).

Table 1. Change in average conditions (basal area, BA) over a 40-yr period (1950s value/1990s value) on the partially cut compartments at the PEF. Adapted from Sendak et al. (2003).

Treatment	# Plots	# Harvests	% BA BF/RS/EH	% BA Hardwoods	Total BA (m^2/ha)
URH	41	2	63/38	21/51	31.0/11.5
FDL	33	3	63/66	14/24	33.2/27.8
MDL	32	3	72/75	17/16	33.8/23.0
S05	33	10	62/78	22/11	28.1/23.2
S10	34	5	73/75	15/16	32.4/22.7
S20	38	3	77/80	6/12	34.8/18.9

Note: BF, balsam fir; RS, red spruce; EH, eastern hemlock; URH, unregulated harvest; FDL, fixed diameter limit; MDL, modified diameter limit; S05, 5-yr selection; S10, 10-yr selection, S20, 20-yr selection.

There was a clear tendency for the model to over estimate live basal area (LBA_{pre}) relative to observations from the remeasurement plots (LBA_{obs}), even after the plot level calibration factors were applied (Figure 1). The disparity was greatest for the URH treatment, where, on average over the length of the simulation, LBA_{obs} was ~40% below LBA_{pre}. Predictions were closest to the observed values for the most intensive treatment (S05), where they provided a mere 3% underestimate of LBA averaged across both compartments over time. We also detected a positive relationship between the amount of BA removed in a harvest and the extent to which the model over predicted LBA.



Note: FVS calibration factors were only available for trees ≥10 cm dbh.

Figure 1. Comparison between observed and simulated conditions (live basal area, LBA) in response to six partial-cutting treatments at the PEF. Observed data is solid lines and symbols with error bars (average of plots within each compartment), the simulated results are dashed (uncalibrated) and dotted (5-yr calibration).

In contrast to LBA, mortality was consistently under represented by the model. For example, while observed rates of ~1 m^2/ha/5-yr were recorded across treatments over time, predictions were for less than half that value (data not presented). Because FVS implements mortality primarily on the basis of a species weighted stand density index (SDI) value (Dixon 2002), predictions of competition induced mortality were low for plots that were less than fully stocked (i.e. <55% of SDI_{max}). Elevated mortality following harvests was observed in a number of the compartments, presumably related to logging damage and not competition, and so would not be expected to be captured by the model. Also, we observe that clusters of trees (i.e. cohorts) in these multi-aged stands may be self-thinning even though the plot level stocking is below the RD threshold.

Model predictions of growth by dbh size class were also biased (Figure 2), even for the treatments that showed good correspondence in terms of LBA (e.g. S05). The most dramatic over estimates were associated with the smallest stems (up to ~20 cm dbh). A comparison of the most recent diameter distributions indicated that considerably fewer small stems were actually surviving than was being predicted by the model (data not presented). Partial cutting at the PEF has resulted in the creation of new age-classes over time while the portrayal of their growth and survival appears to represent the greatest shortcoming the current model. On balance, calibration which does not influence growth predictions for the smallest size class, resulted in a modest but insignificant improvement over this 25-30 yr simulation run (Figure 2).

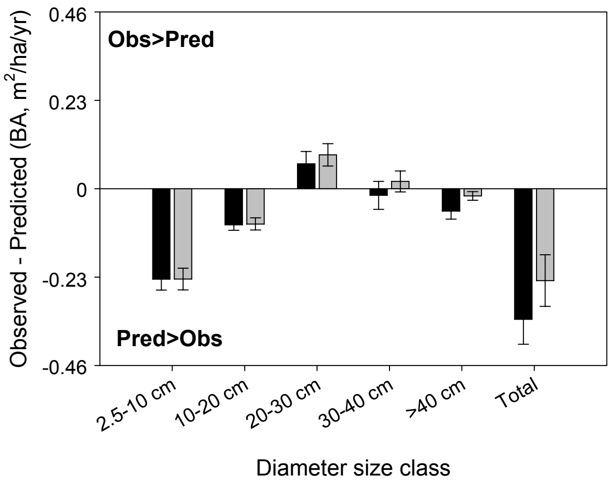


Figure 2. The difference between observed and predicted values for net annual basal area increment by 10-cm wide diameter class. Averages determined across treatments based on calibrated and uncalibrated model runs are presented along with their associated standard errors

To our knowledge this study presents the first comparison of the performance of FVS-NE relative to a long-term independent dataset documenting stand dynamics in multi-aged northern conifer stands; an increasingly prevalent forest condition in central and northern Maine. In general, we found model predictions to be overly optimistic as a result of higher growth and lower mortality than observed; this was particularly true of the smaller diameter stems. Calibration resulted in a modest improvement to the model predictions, although, likely as a result of their only applying to larger stems, was unable to greatly improve the overall results. Based on these findings we recommend that the development team responsible for FVS-NE focus their efforts on more accurately capturing the developmental dynamics (i.e. growth and mortality functions) of the subordinate size/age-classes in these complex multi-aged stands. Further, we believe that adopting the modeling framework employed by the Lake States variant of FVS, which uses information about live crown ratios for predicting tree growth, could greatly improve the performance of FVS-NE.

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Theme: Modeling growth and yield

Soil respiration, microbial biomass and nitrogen dynamics in a hybrid poplar-hardwood-soybean intercropping system in southwestern Québec, Canada

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In temperate regions, tree-based intercropping (TBI) systems are recognized as a valuable land-use practice for improving the profitability of hardwood and hybrid poplar (HP) plantations. However, little is known about soil quality in TBI systems as compared with conventional tree plantations. The objective of this study was to evaluate the influence of two alley treatments (soybean intercrop and disking) in a 6-year-old HP-hardwood (spaced 8 m between tree rows) plantation on soil fertility parameters such as humidity, basal respiration rate, microbial biomass, nitrogen (N) availability and net N mineralization. These variables were measured at different distances from the HP row (0, 2 and 5 m) from June to October 2005. The maximum of variation between treatments was observed 3 weeks after the 2nd disking, in mid-August, with the soybean intercrop reducing soil moisture and basal respiration rate by 21%, and microbial biomass by 16%, as compared with the disking treatment. Nevertheless, at the beginning of September, available N (NH_4^+-N and NO_3^--N) was 26% higher in the soybean intercrop than in the disking plots, indicating a facilitation process that could compensate partially for the reduction of water and carbon availability observed earlier in the growing season. Contrary to results from other studies, indices of soil available C and N increased with increasing distance from the HP row. We hypothesize that this is due to the presence of a leguminous intercrop and to the use of a polyethylene mulch.

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Theme: Tree physiology, carbon and nutrient cycles and genetics

Herbaceous layer composition in relation to environment within a forested watershed

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Abstract

Ecologically based forest management requires consideration of the herbaceous layer. Our objective was to examine relationships among herbaceous-layer composition and factors of the physical environment within a small forested watershed (ca. 56 ha) containing mature mixedwoods stands in southeastern New Brunswick, Canada. Environmental variables and percent cover of vascular plants ≤ 1 m tall were sampled in 169 circular plots ($5m^2$) on transects running from the stream edge upslope to the ridgetops. Canonical correspondence analysis indicated that vegetation composition followed gradients corresponding to elevation, canopy and litter composition, and litter chemistry. The small watershed is a convenient unit for studying vegetation variation among adjacent communities and underlying causal factors. Information at this scale is needed in forest management planning to identify unique communities and habitats for protection or special treatment.

Introduction

Increasing attention is being paid to using the watershed as the basic unit in forest management planning and ecosystem management. Various studies have addressed the impacts of forest harvesting at the watershed scale, typically from the viewpoint of hydrology (e.g. Bormann and Likens 1979). The purpose of this study is to identify gradients in plant species composition within a forested watershed. Knowledge of where particular species and communities occur within a watershed is needed for watershed-level ecosystem management. Our objective is to identify relationships among the species composition of vascular plants in the herbaceous layer and factors of the physical environment within a small forested watershed.

Study area

The study was conducted in a 60-ha watershed in southeastern New Brunswick, Canada. The watershed contained mature (ca. 90 years-old) mixedwood forest dominated by *Picea mariana*, *P. rubens*, *Acer rubrum*, *Betula papyrifera*, *Populus tremuloides* and *Abies balsamea*. Elevations ranged from 70 to 130 meters above sea level. There were eight distinct stand types within the watershed, based on overstory tree composition as indicated on Provincial stand type

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maps. Softwood stands were found at low elevations along the stream, mixedwoods on mid-slopes, and hardwoods on upper slopes and ridgetops (Roberts and Zhu 2002).

Field methods

A total of 169 sample plots were established on transects running from the stream to the ridgetop on both sides of the watershed. The plots were 5 m^2 in area. The interval between plots within transects and between transects was 50 meters. Percent cover of each vascular plant species < 1 m tall was estimated. A total of 34 separate environmental variables were also measured at each plot to characterize canopy and litter composition (deciduous vs. coniferous), topography (microtopography within the plot and topographic position), litter chemistry (from laboratory analysis of surface litter), and plant tissue chemistry (from laboratory analysis of leaves of *Maianthemum canadense*). Species nomenclature follows Hinds (2000).

Analysis

Multivariate analyses were conducted using the program CANOCO (ter Braak and Smilauer1998). To identify gradients in the physical environment within the watershed, we used principal components analysis (PCA). Discrete environmental variables (e.g. stand type) were entered as dummy variables, resulting in a total of 55 variables.

Gradients in vascular plant composition were characterized with detrended correspondence analysis (DCA). Percent cover by species and plot was entered into the program.

To determine relationships between factors of the physical environment and vascular plant composition, canonical correspondence analysis (CCA) was used. Most CANOCO defaults were used, except rare species were down-weighted and 7 plots containing less than 5 species were made supplementary. Forward selection of environmental variables was used to identify the variables that were most strongly related to species composition.

Results

The first two PCA axes indicate the major gradients in the physical environment within the watershed (Table 1). Axis 1 represents a gradient related to elevation. Plots with deciduous canopy and litter, low carbon content of the litter and low amounts of litter occur at higher elevations, whereas plots with coniferous canopy and litter, high carbon content of the litter and high amounts of litter occur at lower elevations. Axis 2 represents a gradient in litter chemistry, from high litter phosphorus, potassium and carbon content at one end of the gradient to low litter phosphorus, potassium and carbon content at the other end.

Table 1. Weights of the most important environmental variables on the first two axes from principal components analysis (PCA).

PCA Axis 1		PCA Axis 2	
Environmental variable	Weight	Environmental variable	Weight
Coniferous canopy	-0.94	Phosphorus in litter	0.93
Deciduous canopy	0.90	Potassium in litter	0.68
Elevation	0.60	Carbon content of litter	0.42
Carbon content of litter	-0.59		
Coniferous litter	-0.58		
Deciduous litter	0.55		
Litter depth	-0.50		

Plots on the low end of DCA axis 1 were characterized by the following species: *Oxalis montana, Gymnocarpium dryopteris, Aster umbellatus, Prunella vulgaris, Solidago flexicaulis, Equisetum sylvaticum* and *Mitella nuda.* At the high end of axis 1 were plots with *Picea rubens, Veronica officinalis, Abies balsamea, Gaultheria hispidula, Betula papyrifera, Dalibarda repens* and *Linnaea borealis.* On axis 2, there was a gradient from *Populus grandidentata, Apocynum androsaemifolium, Antennaria* spp., *Pyrola Americana, Monotropa hypopithys* and *Lonicera canadensis* at the low end to *Thelypteris novaboracensis, Picea mariana, Sphagnum* spp., *Huperzia lucidula, Luzula acuminata, Lycopodium annotinum* and *Acer rubrum* at the high end.

In CCA, nine environmental variables were significantly related to the gradients in species composition ($p \leq 0.01$ for conditional effects). High elevations, ridgetop position, deciduous canopy and easterly aspects characterized plots at the low end of axis 2 (Figure 1). Species associated with these plots included *Monotropa hypopithys, Lycopodium annotinum, Populus grandidentata, Lycopodium clavatum, Cypripedium acaule, Chimaphila umbellata, Pyrola Americana, Lonicera canadensis, Medeola virginiana,* and *Aralia nudicaulis.* Plots with high calcium content in litter, high litter pH, high proportion of moss litter, high plant tissue nitrogen and in stand type 7 were located at the high ends of axes 1 and 2. *Solidago flexicaulis, Prunella vulgaris, Aster umbellatus, A. ciliolatus, Mitella nuda, Ribes lacustre, R. americanum, Equisetum sylvaticum, Oxalis Montana* and *Gymnocarpium dryopteris* were associated with these plots.

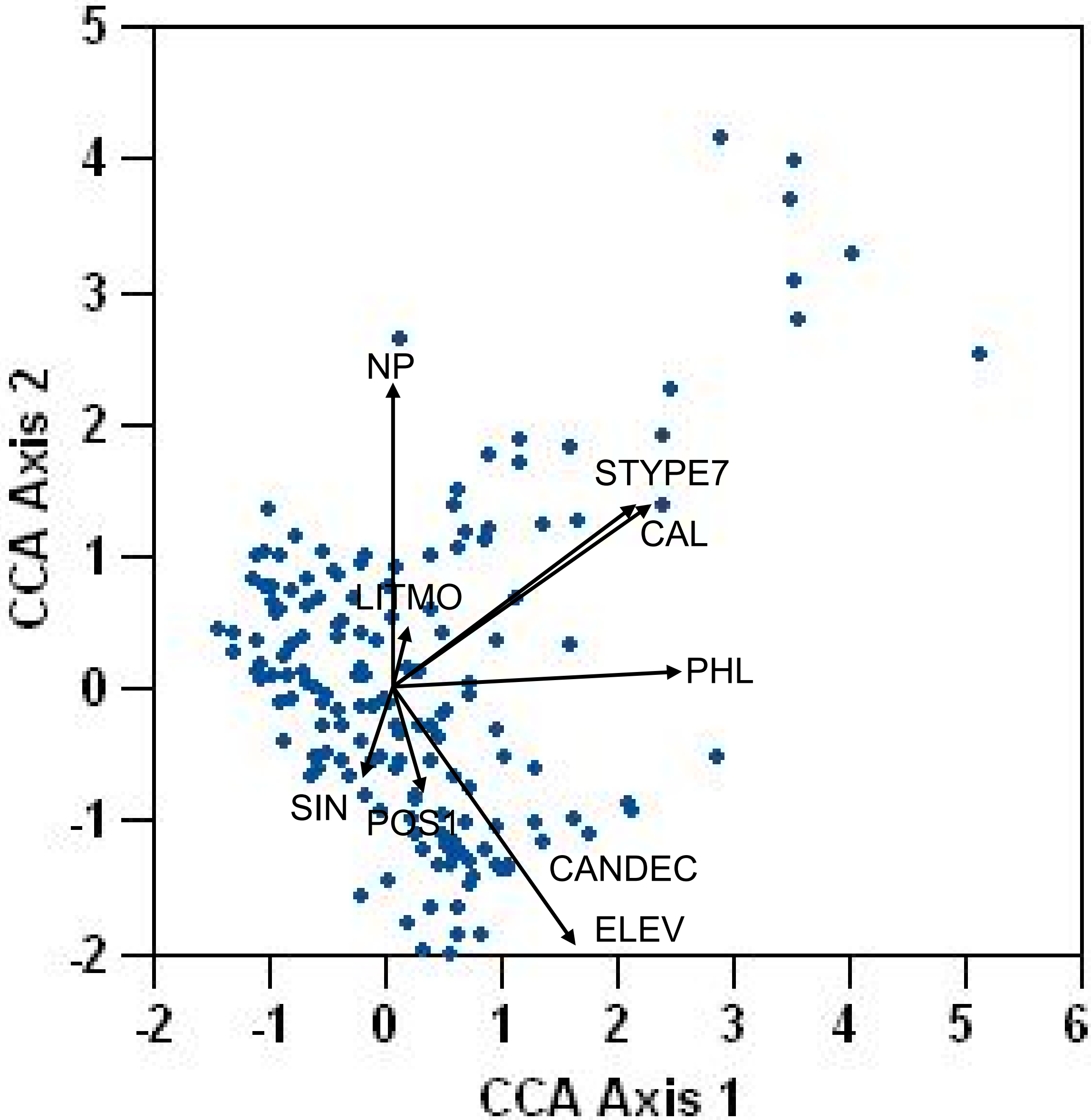

Figure 1. Canonical correspondence analysis (CCA) scatterplot of samples on the first two CCA axes. Environmental variables with significant conditional effects ($p \leq 0.01$) are shown as vectors. The lengths of the vectors have been multiplied by 3 to increase visibility. The environmental variables are: NP, nitrogen in plant tissue; STYPE7, stand type 7; CAL, calcium in litter; LITMO, proportion of litter made up of moss; PHL, litter pH; CANDEC, proportion of canopy made up of deciduous leaves; ELEV, elevation above sea level; POS1, slope position 1 (ridgetop); SIN, sin of aspect (eastness).

Discussion

The primary gradients in the physical environment within the watershed were related to elevation and fertility. Elevation in turn affects canopy and litter composition. The proportions of deciduous canopy and litter increased with elevation as coniferous canopy, coniferous litter and litter depth decreased. Fertility varied from plot to plot in response to local soil conditions.

On DCA axis 1, composition of the herbaceous layer varied from species associated with rich, moist woods (e.g. *Oxalis Montana* and *Gymnocarpium dryopteris*) to those commonly associated with coniferous woods (e.g. *Gaultheria hispidula, Dalibarda repens* and *Linnaea borealis)*. Species varied on the second axis from those in mixed forests, moist forests, barrens and cool woodlands to species that are typically found in wetter habitats, such as *Thelypteris novaboracensis* and *Sphagnum* spp., associated with a canopy of *Picea mariana*. The patterns in understory species composition reflect the overriding gradients in canopy and litter composition (deciduous vs. coniferous) as influenced by broad differences in elevation and fertility.

The specific environmental variables that are most closely related to species compositional patterns were revealed by CCA. The results from CCA confirmed that elevation and other factors related to elevation (i.e. canopy and litter composition, slope position), along with fertility, have the greatest influence on species composition. Surprisingly, sin of aspect (indicating degree of eastness) was a significant variable in the CCA. Sin was inversely related to NP, CAL, PHL and STYPE7, as indicated by the generally opposite directions of the vectors (Figure 1). Indeed, sin was significantly inversely correlated with most plant tissue and litter nutrient variables (data not shown), suggesting that the east aspects in this watershed are underlain by less fertile soils.

One of the most important environmental variables in CCA was STYPE7. This stand type was unique, containing *Fraxinus Americana* and *Ostrya virginiana* in the overstory. It was also the most fertile site in the watershed. The seven plots at the high ends of both CCA axes (Figure 1) were all located in this stand type, reflecting its strong influence on fertility and compositional patterns.

The most important environmental variables identified in CCA differed in some cases from those that had the highest weights in PCA. The important variables in terms of identifying environmental gradients are not necessarily those that have the highest correlation with species composition.

Conclusions

The watershed provides an ecologically-based unit for ecosystem management. Conservation of the herbaceous layer in forested watersheds requires knowledge of where unique species and communities can be found within the watershed. Species composition can be predicted from easily measured environmental variables. The environmental variables must be carefully selected, however, to be sure that they are strongly correlated with species compositional patterns. In the case of this watershed, elevation, canopy composition and fertility were the environmental gradients that provided the best explanation of differences in species composition of the herbaceous layer.

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Theme: Forest ecosystems

Regenerating high-graded yellow birch stands

Ruel, Jean-Claude[1], Pierre Gastaldello[2], Jean-Martin Lussier[3], and David Paré[3]

Abstract

Many yellow birch-balsam fir stands have developed into unproductive stands as a consequence of past high-grading practices. This study attempts to induce natural regeneration of yellow birch, taking advantage of residual mature trees. Four open stands dominated by yellow birch, with a heavy shrub understory were selected. Strips were brushed and seed-spot scarification was applied within the strips. Seed rain and regeneration on different seedbeds were monitored for three years. After 3 years, an additional experiment measuring the effect of competition and hare browsing was added. Results show that it is possible to establish an abundant regeneration on scarified patches using residual trees but that its further development can be compromised by browsing, low light levels or poor nutrient availability.

Introduction

Past harvesting practices applied in the yellow birch range have often led to the creation of poor-quality stands (Robitaille et Roberge 1981; Metzger et Tubbs 1971). This is especially true for diameter-limit cuts which focused on short-term financial return. The abundance of these poor quality stands in the balsam fir-yellow birch ecological domain poses important regeneration challenges. Residual trees remain on the site but their potential as seed trees has not been verified. In addition, a well-developed shrub layer dominated by non commercial species and the rarity of favourable seedbeds inhibit seedling establishment. The purpose of the study was to test a natural regeneration approach using the potential of residual seed trees.

Methods

Four open, high-graded stands dominated by yellow birch were selected, 130 km NW from Quebec City. Prior to a diameter-limit cut, they contained a significant component of softwoods. Strips (6 m) were brushed in fall 2000, alternating with untreated strips. In the cleaned strips, seed-spot scarification was applied. Seed dispersal was monitored on an annual basis for the first

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three years. Regeneration was monitored on: 1 m wide scarified patches, 2 m wide scarified patches, undisturbed litter and mounds made from the material removed from the patches. Seedlings were tallied up to a maximum of 200 seedlings/m^2. Variations in nutrient availability and seedling growth in relation to the position within the scarified patch were studied. Nutrient availability was assessed with PRS probes. In 2003, an additional experiment was installed. Fifty microsites were selected within the patches and mounds. Combinations of browsing control treatment (exclosure, no exclosure) and vegetation control (removal of competing vegetation, no treatment) were applied on the various microsites. Growth and mortality of individual seedlings were monitored.

Results and discussion

Over the three years of seed dispersal monitoring, one was exceptional, one very good and one very poor with respectively 2931 seeds/m^2, 1014 seeds/m^2 and 7 seeds/m^2. Local seed rain was not related to the local abundance of seed trees since seed production was highly variable between trees. Seedling establishment was in direct relationship with seed crop. Seed rain from the residual trees was more than sufficient to ensure adequate regeneration on disturbed seedbeds during good seed years (Figure 1). The effect of seedbed type was significant, even during the third year, suggesting that scarified seedbeds were still receptive after three years. This confirms previous observations from many authors on the impact of undisturbed litter on yellow birch germination (Godman et Krefting 1960, Houle 1992, Houle et Payette 1990, Erdmann 1990).

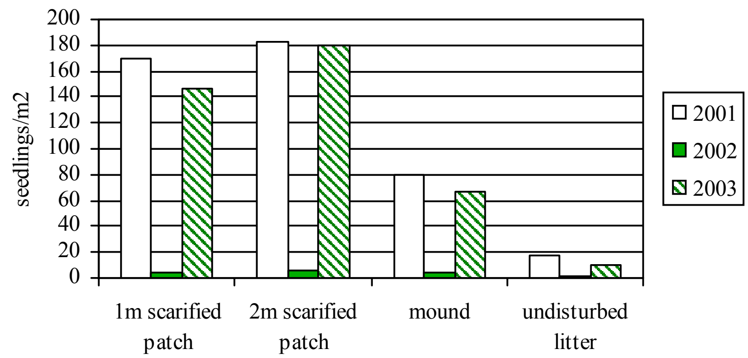

Figure 1. Yellow birch establishment by seedbed type

However, seed availability in these open stands as well as the persistence of the scarification effect were less documented.

Scarified, mineral seedbeds offer good conditions for germination, especially due to a constant moisture supply. However, concerns have been expressed regarding seedling nutrition on this seedbed type (Marquis 1965; Hoyle 1971 and 1979). The detailed monitoring of nutrient availability confirmed that many nutrients were less

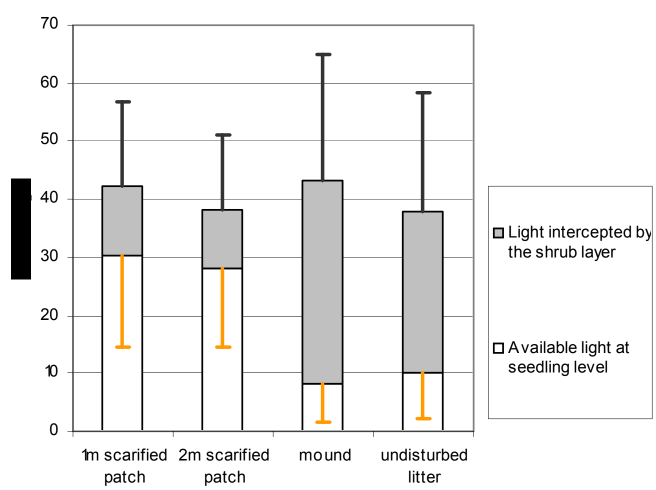

Figure 2. Light availability at the third growing season

abundant in scarified patches in comparison with mounds or undisturbed litter. Nutrient availability was sometimes better at the edge than at the centre of scarified patches. Best seedling growth occurred on mounds and at the edge of scarified patches, suggesting a direct relationship with nutrient availability.

Even though mounds produced the largest seedlings after two years, the effect of microsite was non significant after three years. In addition, the amount of light that they were receiving at that time was very low (Figure 2). The amount of available light was greatly reduced by the shrub layer that came back on mounds and undisturbed plots. According to Logan (1965) and Godman and Krefting (1960), 45-50% of full sunlight would be required once the seedling is established.

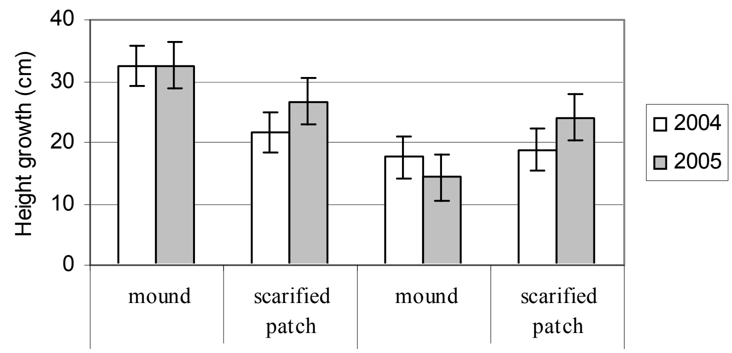

Figure 3. Height growth in fenced plots

The exclosure experiment confirmed that browsing was a significant factor limiting seedling development. Mortality was 2-10 times higher in unfenced plots, reaching 24%. In fenced plots, vegetation control had a significant impact on seedling growth on mounds but not in scarified patches (Figure 3). This suggests that competition was not critical in scarified patches or that nutrient availability was the main factor. The fact that growth was better on fenced mounds with vegetation control in comparison with fenced scarified patches with vegetation control suggests an impact of nutrient availability. The situation is very different in unfenced plots. In these conditions, growth was generally poorer for released seedlings (Figure 4). This could suggest that, by removing alternatives food sources and making the seedlings more visible, release treatments could increase browsing pressure on the seedlings.

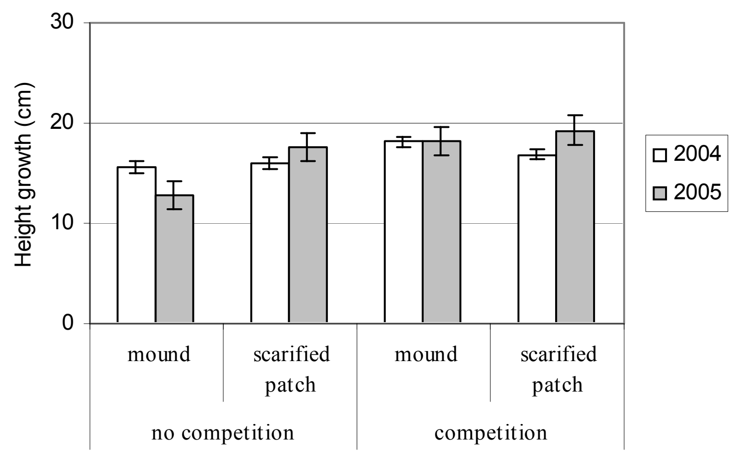

Figure 4. Height growth in unfenced plots

Conclusion

This study has showed that it is possible to establish natural yellow birch regeneration from residual seed trees in open, high-graded stands. Seed production appears sufficient but seedling establishment will be greatly enhanced by seed-spot scarification. This treatment will reduce competition for light but at the same time will reduce nutrient availability. Seedling development is strongly affected by hare browsing and competing vegetation. In the absence of treatment addressing these factors, the future fate of established seedlings remains unsure.

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Theme: Silviculture

Modelling the respective effects of habitat loss and fragmentation on forest birds and small mammals in eastern Canadian boreal forests

St-Laurent, Martin-Hugues[1], Jean Ferron[2], Christian Dussault[1,3] and Réjean Gagnon[4]

Habitat loss (LOSS) and fragmentation (FRAG) are known as major threats to biodiversity worldwide. However, their respective effects on wildlife are sometimes confounded when measured in logged landscapes. At the landscape scale, LOSS is often recognized as the most prominent source of fluctuation in animal densities and species richness. Yet, LOSS effects on wildlife in residual forest fragments have received very little attention. In order to discriminate between such influences, we employed habitat use models (HUMs) built for 12 bird and 2 small mammal species with empirical data from residual and undisturbed mature forest stands. We then back calculated densities for 16 different patterns of LOSS and FRAG, as well as for three theoretical landscapes (LAND) that differed according to the number and position of roads, lakes and streams. We found that: 1) following variance partitioning, LOSS had the largest influence (45.2%) on species relative densities, while FRAG only explained 24.5% of the variability, 2) LAND had the second largest influence (38.5%), and 3) the effects of LOSS, FRAG and LAND varied according to species. Our results therefore suggest that LOSS should be limited in order to ensure the maintenance of area-sensitive species within logged landscapes. Our results also suggest that the configuration of residual forests must take into account the structure of local stands as well as their position relative to roads, streams and lakes.

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Theme: Wildlife

Comparing site index by site types along an ecological gradient in southern Québec using stem analysis

Saucier, Jean-Pierre[1], Claude Gagné[2] and Sylvain Bernier[2]

Abstract

Site index is a common measure of productivity in forestry but is difficult to assess accurately from forest inventories because selected dominant trees may not have been dominant and free to grow for all their life. In many species that are shade tolerant, juvenile suppression is common. Some species are also subject to insect outbreaks and may show irregular growth patterns. These two processes, competition and predation, are affecting height growth more severely on the sites that are considered to be more fertile according to the forest ecological classification, thus creating fuzziness when comparing site index and site types. Using stem analysis to detect growth incidents that negatively influence the relationship between age and height, methods have been developed to estimate the growth potential of a site type without growth delays. With mixed models, taking into account the effect of individual stems and of repeated measures from stem analysis, growth patterns are compared among site types in an ecological region and for a similar site type between ecological regions. The results are intended to serve as a basis for growth models and to help forest managers to decide whether or not they should invest in a particular site type.

Introduction

Site index is a common measure of productivity in forestry but is difficult to assess accurately from forest inventories because selected dominant trees may not have been dominant and free to grow for all their life. In many species that are shade tolerant, juvenile suppression is common. Some species are also subject to insect outbreaks and may show irregular growth pattern. Those two processes, competition and predation, are affecting height growth more severely on the sites that are considered to be more fertile according to the forest ecological classification, thus creating fuzziness when comparing site index between site types.

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Using stem analysis to detect growth incidents that influence negatively the relationship between age and height, methods have been developed to estimate the growth potential of a site type in absence of growth delays. With mixed models, taking into account the effect of individual stems and of repeated measures from stem analysis, growth patterns are compared among site types in an ecological region. The results are intended to serve as a basis for growth models and to help forest managers to decide whether or not they should invest on a particular site type.

Objective

The objective of this project is to assess the site index for different ecological site types (or land types) and to compare them along a landscape gradient in a particular ecological region. The results of the study are to be made available for the forest managers to help them identify the most productive ecological types in a management area.

Materials and methods

Sampling plan

Two levels of the ecological land classification of Québec (ELCQ) hierarchical system have been chosen as the basis for the sampling plan: ecological region and ecological site type. (Saucier et al., 1998). An ecological region is an area characterised by its main physical features, by the forest dynamic observed on mesic sites and by the distribution of ecological site types in the landscape. Ecological regions are mapped with a bottom up approach by grouping regional landscape units that share common range of relief, geology, hydrography and climate (Robitaille and Saucier, 1998). An ecological site type is an area, at local scale, with a permanent combination of potential vegetation and site characteristics. Potential vegetation express the different paths of forest dynamics while a combination of soil texture, soil moisture regime and topographical position express the site characteristics. The concept of ecological site type is equivalent to the concept of sites series in the biogeoclimatic classification of British Columbia (Pojar et al., 1987) with more emphasis on the forest dynamics through the potential vegetation concept. Using an ecological land classification based on factors related to growth, like climate, soil and site characteristics, for the sampling scheme allows to generalise the site index values by applying them to an integrated ecoforest map.

For the purpose of this paper, we selected data from two ecological regions (Saucier et al. 1998). Subset A is made of 220 stems of black spruce and balsam fir from ecological region *5b-Coteaux du réservoir Gouin*. Subset B is made of 67 stems analysis of black spruce from ecological region *5d-Collines ceinturant le lac Saint-Jean* and will be used for comparisons.

Data collection and growth analysis

In each plot, stand and site characteristics are observed and all merchantable trees are tallied. The plot is also classified according to a «Field guide for identification of ecological site ype» specific to each ecological region. Trees to be felled are selected in the forest by MRNF crew according to several criteria: dominant or co-dominant tree; with no apparent defects; without severe growth reduction as showed on a sample core extracted at the height of 1m. Crown width and distance to neighbours are measured prior to felling to assess competition. After the felling, total length of the tree is recorded and disks are collected at 0,15 m, 0,60 m, 1,00 m, 1,30 m, 3,00 m and then every 2,00 meters to the top of the tree. Disks are taken to the lab, dried, sanded, pre-counted and scanned. The increments are measured with WINDENDRO along four radiuses for the four lowest disks or for irregular disks and along two radiuses for the rest. The stem is submitted to interdatation with COFECHA to ensure a perfect match between the radius of each disk and between disks along the stem. Data is then stored in a central database. This lab work is done by contractors and audited by MRNF crew.

From the stem analysis data, increments in diameter, in height and in volume are computed with a program called ANATI, developed by MRNF research branch. For height growth we used the method that assumes that height growth is constant between adjacent sample disks and that the disks are located at the midpoint of an annual height increment. The same method has been used by Huang and Titus (1992) and others.

Correction for juvenile growth suppression

Even if each tree was cored in the forest prior to be selected for felling, the analysis of individual height growth patterns often show one or more events of reduced growth and release. Those events are not obvious in examining the diameter growth pattern and can be missed while looking at an increment core sample in the forest. As we want to express the potential of the site, the effect of those growth reductions must be tempered. One way is to eliminate such stems from the analysis but it may be difficult to find trees without any suppression for some species that are shade tolerant. Those species can survive long periods of juvenile suppression, waiting for overtopping trees to fall or to be cut, and later become a dominant tree. A common way to reduce the effect of juvenile growth suppression is to change the reference height at which the age is taken. In Québec, reference height is 1,00 m (Pothier et al., 1998) to avoid coring of trees at breast height in permanent sample plots. Trees usually show much less juvenile suppression over this height of reference thus minimizing the effect of juvenile growth suppression. Despite that, certain tolerant species still show juvenile growth suppression or other height growth reduction periods along the stem. Decision was made to identify growth reduction periods and correct them in order to better establish the height growth potential of the ecological types.

A juvenile height growth suppression period is defined as a period of 5 consecutive years or more, located in the early age of the stem, where the height growth of the stem is lower than the mean height growth by age by at least three times the standard error of the mean followed by an evidence of release. Trees without juvenile height growth suppression are pooled by ecological type and modelled with the Chapman-Richards function (equation [1]) to make a guide-curve that will be used to correct juvenile growth suppression on trees where it have been detected.

[1] $$H = 1{,}0 + b_1[1 - \exp(-b_2 \times A)]^{b_3}$$

where H= total height in m
A= years since the tree reached the 1,0 m height reference
exp= exponential of the base of Naperian log
b_1, b_2, b_3 parameters to estimate

For this correction, the height growth of each years of the juvenile growth period is replaced by a value randomly selected from one of the guide-curves The part of the stem without suppression is simply added at the end of the corrected period.

Growth reduction by insect epidemics

Many events, other than the juvenile suppression, can cause growth reduction along the stem during the life of a dominant tree, like weather related damage of the stem or insects epidemics. To identify which period of growth reduction is caused by insect epidemics, we used data from annual aerial surveys made by MRNF to assess damage by spruce budworm (*Choristoneura fumiferana* Clemens), Swaine jack pine sawfly (*Neodiprion swainei* Midd.) and Forest tent caterpillar (*Malacosoma disstria* Hubner). Observations made yearly since 1938 form a spatially defined vector of presence/absence of insect damage on trees. When a growth reduction period is identified on a stem, infestation records for this particular location are consulted to be sure that this reduction can be attributed to a specific insect epidemic. If the cause of the reduction can be attributed to an insect epidemic, the growth reduction period is then replaced by the number of years necessary to reach the height of the tree at the end of the period if it had experienced a regular growth. If not, no correction is made because the reduction cause is unknown.

Modelling and estimating techniques

When relating height to age of a tree it is desirable to use a biologically realistic function that can express the relatively slow juvenile growth, the period of fast height growth after installation and release and, finally, the decreasing rate of growth associated with ageing of a stem to reach an asymptote. The Chapman-Richards function (equation [1]) was selected from previous work because it adjusts well to those phases and because each or the three parameters can easily be related to a characteristic of the curve. Because stem analysis are time series and of the nature of the function selected, estimation method is a mixed model with repeated measurements. This model is adjusted to the corrected stems with a SAS program called FITNLM (Lapointe, 1995) that uses the SAS macro NLINMIX with an autoregressive structure AR1. We use fixed effects to express the mean of all the ecological site types considered and random effects at the level of the stem and at the level of the ecological site type where it belongs.

For each species in an ecological region, model is adjusted simultaneously to those ecological types for which at least 20 stem analysis are available. Using FITNLM, we can specify the structure of variance-covariance as homogeneous or heterogeneous. Each resulting curve is first evaluated graphically and then with Akaike information criterion (AIC). The model with the lowest AIC is considered to be the best.

Comparison among ecological sites types

Comparison between ecological site types is made not only on the value of the site index at the age of reference (50 years at 1 m reference height in our case) but also on the shape of the height growth curve. Sites index curves are compared, two at a time, for the same species, between the ecological site types of one ecological region with the statistic of Wald, as described in Vonesh et Carter (1992). The fixed parameters for each ecological type are used. The null hypothesis that the two groups are similar. The comparisons are made with a significance level of α / c where α is fixed at 0,05 and c is the number of comparisons made, as suggested in Bonferoni's method for multiple comparisons. Results of those tests are interpreted and ecological sit types without statistical difference are grouped together considering also the ecological classification logic. If new groups are created at this step of the analysis, the estimation is done again to produce a final set of site index parameters.

Results and discussion

Correction of juvenile suppression and growth reduction periods

Despite careful selection of trees prior to felling, few trees show no juvenile suppression or other growth reduction. It is especially true in balsam fir where only 10 to 20% of the trees are free of reductions depending on ecological site type (table 1). Juvenile growth suppression is important in subset A where 46 % of black spruce trees show a mean suppression period length ranging from 8,5 to 11,0 years depending of ecological site type. For balsam fir, 67% of the stems show juvenile suppression and the mean suppression period is longer, ranging from 11,5 to 14,6 years. These relation can differ among ecological region. For example only one third of black spruce stems show juvenile suppression in subset B. Influence of growth reduction period on site index have also been demonstrated by Seymour and Fajvan (2001) on red spruce.

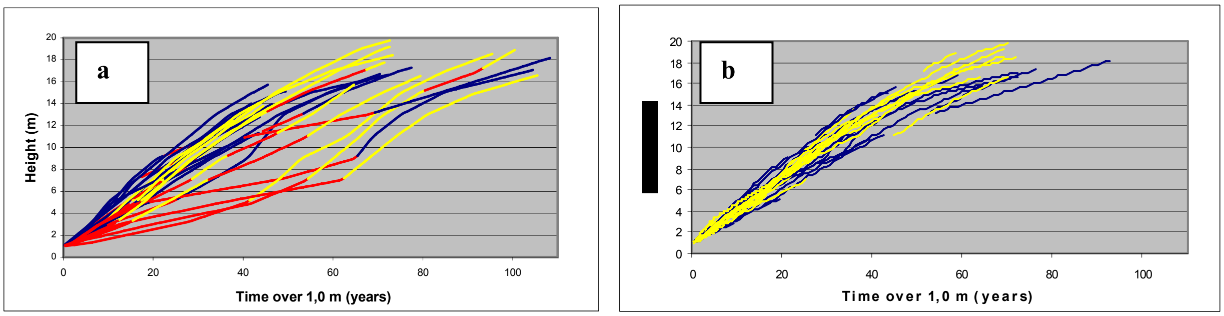
Table 1: Juvenile suppression and growth reduction caused by insect epidemics

Ecological region	Species	Ecological site type	Number of stem analysis	No growth reduction		Growth reduction caused by juvenile suppression			Growth reduction caused by insect epidemics			Both growth reduction cause	
				n	%	n	%	nb an cor.	n	%	nb an cor.	n	%
Subset A 5b	EPN	RE21	38	17	45	17	45	8,5 (± 5,9)	7	18	3,1 (± 2,0)	3	8
		RE22	40	18	45	18	45	8,8 (± 4,6)	10	25	4,8 (± 3,1)	6	15
		RE25	25	5	20	13	52	10,6 (± 13,7)	11	44	8,6 (± 8,9)	4	16
		RS22	42	15	36	19	45	11,0 (± 6,0)	18	43	4,4 (± 4,0)	10	24
	SAB	MS22	46	9	20	28	61	11,5 (± 11,0)	29	63	8,6 (± 4,5)	20	43
		RS22	29	3	10	22	76	14,6 (± 12,9)	16	55	10,0 (± 5,3)	12	41
Subset B 5d	EPN	RE20	22	13	59	6	27	5,4 (± 5,1)	5	23	2,8 (± 1,6)	2	9
		RE21	25	9	36	12	48	4 (± 2,2)	8	32	4,1 (± 3,0)	4	16
		RE22	20	12	60	4	20	3,4 (± 2,9)	6	30	6,4 (± 7,0)	2	10

Note : EPN is french acronym for black spruce and SAB for balsam fir.

The frequency and length of growth reduction effect of spruce budworm epidemics is more important for balsam fir, known to be more sensitive to this insect, than for black spruce. Those reduction affect 60% of balsam fir stems in subset A for a mean reduction length ranging from 8,6 to 10,0 years. For black spruce the effects are shorter, from 3,1 to 8,6 years, and affect only 32% of the trees. Some trees, in fact 16% of the black spruce and 43% of the balsam fir of subset A, are affected by both causes of growth reduction.

Figure 1 shows growth pattern for individual stems, from one particular ecological site type, (a) before and (b) after correction for juvenile suppression and growth reduction caused by insect epidemic. The wide distribution of the growth curves before correction is typical of what is usually observed, even if only dominant trees were selected. However the individual curves show a similar slope for certain periods between 3 and 16 m height. The corrected parts of the stems are those who add variability in the age and height relationship. After correction, the general form of the curves follows a more regular pattern and the distribution is narrower even if some natural variability persists.



Note: Red lines are periods of growth reduction from juvenile suppression or other growth reduction; blue lines are periods without correction from stems without juvenile suppression; yellow lines are periods without correction from stems with juvenile suppression in (a) and corrected stems in (b).

Figure 1: Growth pattern for black spruce on ecological site type RE25, in ecological region 5b before (a) and after (b)correction for suppression and growth reduction.

Comparison among ecological sites types

For each ecological region, a set of site index values is produced with confidence limits at 95% (table 2). Asymptotes values, given by parameter β_1, are also checked to be sure that they are realistic. Wald's test for comparison among ecological site types show that site index curves are significantly different for black spruce between all four ecological site types of subset A (Figure 2). Differences in site index value, fifty years after the tree reached 1,0 m are not far from each other, ranging from 13,8 to 15,7 m, but the curves are compared on all parameters and show different shapes.

Ecological classification logic is verified for black spruce because the more nutrient medium-rich mesic site (EPN RS22) with a coniferous dynamic have a better site index than the nutrient poor acidic dryer sandy sites (EPN RE21). The two other ecological site types are in between, the sub-hydric site (EPN RE25) having a different shape. For balsam fir, the more nutrient rich mesic site (SAB MS22) with a mixedwood dynamic have a better site index than the medium-rich mesic site (SAB RS22). For the same ecological site type (RS22), site index curves for black spruce and balsam fir have very similar shape and level.

Not all comparisons are as easy. For example, in ecological region 5d (subset B), black spruce curves show significant difference between medium-rich mesic sites (EPN RE22) and sites with very thin soil (EPN RE20). But each of those curves show no significant difference with the nutrient poor acidic dryer sandy sites (EPN RE21). In such a case, ecological interpretation should be used to decide whether or not to group those curves or to keep them separate. Those cases occur when growth patterns on each sites are highly variable and when there is an overlap of variance between ecological site types.

Table 2: Site index by species and site type

Ecological region	Species	Ecological type	Number of stem analysis	Site index(m) SI	L95	U95	Asymptote (b1)	Difference
Subset A 5b	EPN	RS22	42	15,71	15,14	16,29	24,09	a
		RE25	25	15,22	14,55	15,90	26,06	b
		RE22	40	14,33	13,78	14,88	23,40	c
		RE21	38	13,77	13,25	14,30	24,05	d
	SAB	MS22	46	18,12	17,41	18,83	27,72	a
		RS22	29	15,51	14,55	16,47	22,55	b
Subset B 5d	EPN	RE22	20	16,92	15,67	18,16	26,82	a
		RE21	25	16,36	15,34	17,37	27,97	a b
		RE20	22	13,99	12,86	15,13	22,93	b

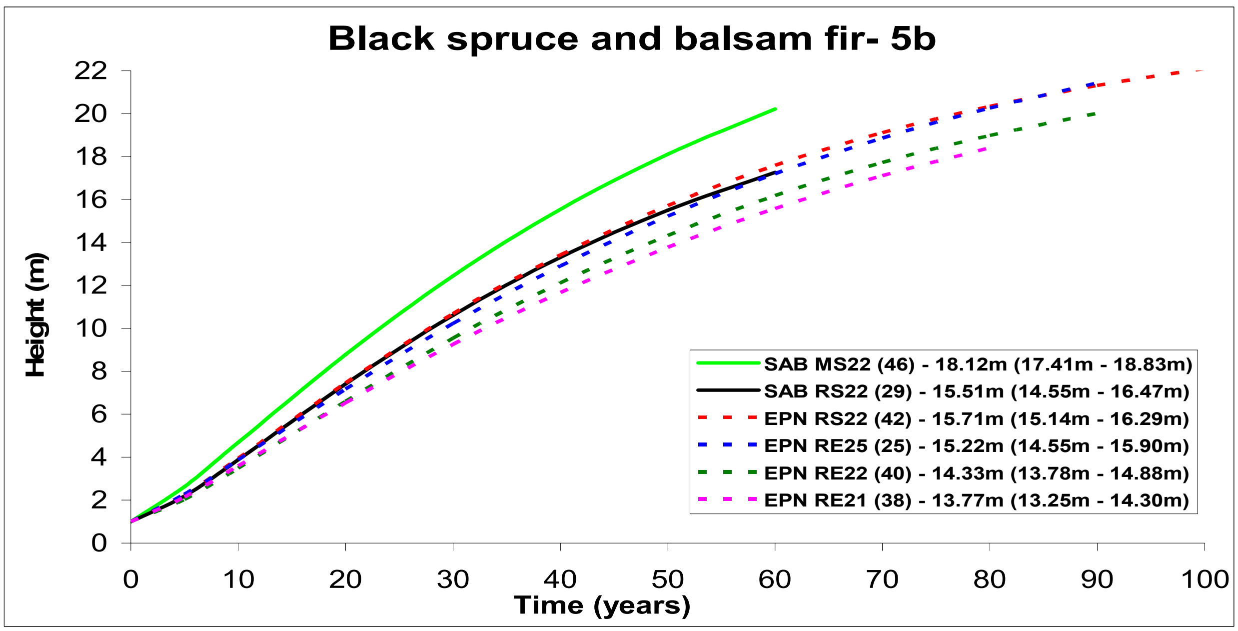


Figure 2: Site index curves for black spruce and balsam fir on different ecological site types, in ecological region 5b-*Coteaux du réservoir Gouin*.

Conclusion

Those results show that correction of juvenile suppression and growth reduction is necessary for the stem to express the real potential of the site. Without such correction the differences between the ecological site types become fuzzy. When tested on all parameters of the curves, significant differences are found among many ecological sites types. Most of the time those differences are consistent with the logic of the ecological classification. Those site index curves are useful for comparison of sites but may not well represent adequately the height growth of a stand where competition and predation could cause somewhat important delays.

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Theme: Modeling, growth and yield

Modeling the effects of site index and precommercial thinning intensity on end of rotation yield and net revenue

Saunders, Mike R.[1]

Precommercial thinning (PCT) is one of the most costly investments that a landowner can make to a stand. PCT is thought to increase the growth and total merchantable yield of individual trees, but this relationship may not hold at the stand level since unthinned stands have vastly more, albeit smaller stems. Further, there are tradeoffs at both the stand- and tree-levels with harvest costs, rotation length, and bucking optimization that will vary by the intensity of PCT and site index, as well as the timing of any commercial thinning (CT) entries. Yield and financial analysis of PCT/CT regimes in red spruce and balsam fir stands in the northeast have been lacking due to these multiple tradeoffs as well as a general lack of growth models capable of adequately modeling growth responses from PCT. I will present a decision support tool that can use data from individual-tree or stand-level growth models. The tool optimizes merchantable volume for up to three product classes from either inputted tree lists or a stand diameter distribution, and then visualizes the yield and financial return across a range of CT and final harvesting scenarios for a given PCT residual density and site index.

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Theme: Modeling, growth and yield

Effect of silvicultural regime and exploitative harvesting on long-term spatial dynamics of an Acadian forest

Saunders, Mike R.[1] and Robert G. Wagner[2]

Structural changes due to silvicultural regime and exploitative harvesting were spatially analyzed for data from 1974-2002 within 50 nested inventory plots across ten compartments of the long-term silvicultural experiment at the Penobscot Experimental Forest in east-central Maine. Regardless of silvicultural or harvesting treatment, regeneration events increased aggregation in spatial pattern and reduced species intermixing. This pattern was heightened in exploitative harvesting treatments where hardwood densities were much higher. Regular spatial patterns were rare, occurring only in trees >11.4 cm diameter and within the two most recent inventories of a precommercially thinned shelterwood. Both differences among height differentiation values for individual trees and compartment-level average relative Stand Complexity Index (*rSCI*; from Zenner 2000) were generally highest in the natural areas and 5-year selection compartments, intermediate in commercial clearcut and fixed diameter-limit compartments, and lowest in 3-stage shelterwood compartments. After a short adjustment period, precommercial thinning in a shelterwood compartment generally increased species intermixing, height differentiation, and *rSCI*. Results suggest that the natural areas represent two divergent, yet common, pathways of structural development in northeastern forests, and that uneven-aged management more closely resembles these dynamics than shelterwood, commercial clearcut or fixed diameter-limit harvests.

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Theme: Silviculture

Development of a process-based growth simulator for jack pine plantations

Schneider, Robert[1], Frank Berninger[2], Chhun-Huor Ung[3], Pierre Bernier[3] and Tony Zhang[4]

Initial density of the softwood plantations in Quebec was decreased in the early 1990s to decrease costs without fully understanding the implications of this decision on the growth and yield and on the wood quality of the future stand. Furthermore, the interaction between thinnings, initial stand density and site fertility on the growth and yield and wood quality of plantations are not very well known either. We are presently developing a process-based growth simulator for jack pine plantations based on the CroBas model in order to address some of these questions before experimental plots become mature enough to provide empirical evidence. The simulator will have a wood quality module for predicting branch diameter and insertion angle as well as wood density and bending strength of the stem. The underlying allometric relationships used within the simulator have been calibrated using linear and non-linear mixed-effects models to account for the hierarchical nature of the data. The results of these regressions are used to present the principles underlying the simulator. Initial simulation and validation results are also to be presented. Validation is based on data from sample plots spread throughout eastern Canada.

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Theme: Modeling, growth and yield

Modeling black ash (*Fraxinus nigra* Marsh.) habitat for west-central New Brunswick

Sockabasin, Krista A.[1], D. Edwin Swift[2], Charles L.A. Bourque[1] and Fan-Rui Meng[1]

Abstract

Black ash (*Fraxinus nigra* Marsh.; bA) has an important cultural role for Maliseet First Nation's people. The species has no major value as a timber resource in the region because of the wood's inferior structural integrity with respect to lumber uses. However, this same property makes bA ideal for basket making, a traditional Maliseet interest. Prediction of species distribution is necessary for sustainable forest management and restoration of bA. Using species occurrence data and site characteristics of bA, a habitat suitability model was developed to predict the occurrence of potential bA sites on Tobique First Nation land. We intend that this model be used as a tool to assist in the restoration of this culturally significant species, and to "open the door" for its sustainable management for future generations.

Key Words: ecological modeling, habitat modeling, non-timber resource, Tobique First Nation.

Introduction

Black ash (*Fraxinus nigra* Marsh.; bA) commonly occurs as a medium-sized tree in clumps or mixtures along waterways and in water-saturated areas. Although bA is not used by the forest industry in New Brunswick (NB), it is a highly desired tree species in the non-timber industry of basket making. Basket making has an important cultural role with the Maliseet First Nation's people along the St. John River. Currently, limited information exists on the ecology and management of bA in NB (Ecosystem Classification Working Group 2003).

Sustainable forest management requires knowledge of species habitat requirements and current and potential distribution. Ecological modeling techniques that use GIS can not only provide a valuable tool for the sustainable management and restoration of existing forest resources, but also augment our knowledge of the ecological role and ecology of specific species. In 2005, a study was initiated to model the habitat suitability of bA on Tobique First Nation land in west-central NB.

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The objectives of this study were to: (*i*) predict potential sites for bA through ecological modeling, and (*i i*) verify model accuracy by comparing model predictions to field-determined occurrences of bA sites. This paper presents the methods used in developing this habitat model, and shows preliminary comparisons with field surveys of bA sites.

Methods and materials

Study Area

The study area (Tobique First Nation land) is located in the northern portion of Victoria County along the upper St. John River in west-central NB (46°78'N, 67°69'W). The total land base is 2400 ha, of which 1800 ha is forested. The study area lies within Blue Bell Ecodistrict of the Valley Lowlands Ecoregion, which is characterized by softwoods, hardwoods, and mixed forests in the valleys and along the ridges of the rolling landscape (Ecosystem Classification Working Group 2003). The land base is home to 2000 people (Sockabasin, Tobique First Nation Forestry, *pers. comm.,* 2006*)*. Tobique First Nation was chosen for this study because of the people's strong cultural ties to basket making, and the enhanced traditional and historical knowledge of bA site requirements and occurrence in the local landscape.

Model Development

Environmental variables, such as climate and soils, land-use, and elevation are used collectively in predicting bA distribution after the methods described in Bourque et al. (2000). According to Dymond and Johnson (2002), the fundamental resources needed to map current and future spatial patterns in biota are the digital elevation model and climate data. The case-based ecological mapping system used in this study is based on the assumption that a species will be found in locations similar to those areas already inhabited by that species (Renn 2004). Inputs into the model include a 10-m resolution digital elevation model of the Tobique First Nation (DEM). The depressions in the DEM identify features such as rivers, streams, and lakes, which, along with the GIS hydrological layer, can be used to generate a slope-to-position map (SP; or depth-to-water-table map) The SP map displays the static, long-term distribution of wet and dry areas within the landscape. Other model inputs include solar radiation, climate (w.r.t. temperature or growing degree days), and soil fertility maps. All maps use the DEM in their definition in one way or another. Solar radiation and growing degree days define the distribution of warmth (or lack thereof) according to slope and slope orientation (warmer south-facing vs. cooler north-facing slopes) and diurnal processes, such as the drainage of cold air at night time (Bourque and Gullison 1998).

Field Sampling

The objectives of the field research were to: (*i*) determine the accuracy of the predictive model, (*ii*) describe the resource, and (*iii*) obtain a better understanding of the ecology of bA in central NB. Potential bA sites identified by the model were located using aerial photos and traditional knowledge from community elders; information from the elders was particularly significant for the sites that were not identified as suitable by the model. Circular fixed-area plots of 200 m^2 were randomly placed in areas identified as suitable for bA growth. Tree (i.e., species, age, DBH, height for bA only, crown class, and tree condition) and site data (i.e., % overstorey cover, soil texture, soil water conditions, drainage, location to running water, site class, and ground plant occurrence) were collected in plots where bA was observed to occur. Only site information was collected at sites where bA was absent. GPS locations were recorded for each plot for geo-referencing and mapping in GIS and for future visitation. A basket-rating value was assigned to all bA in the plot based on the characteristics used by traditional basket makers. Regeneration was recorded by species and height in three small circular plots in the main plot, each 5 m^2.

Results and discussion

A preliminary map was generated to show the locations for potential habitat of bA on Tobique First Nation land (Figure 1). Best sites for bA growth and development are displayed in red, with moderately suitable habitat in yellow. Suitable bA habitats are found on the lower floodplains of the St. John River. Black ash prefers sites with poor drainage and high soil moisture. The best sites for basket-making materials (bA with the highest basket-rating values) are those sites with free flowing water nearby. A field survey of predicted high-value sites has revealed that 84.6% of the sites visited (11 out of 13 sites) actually had bA growing there. We anticipate that current environmental assessments of suitable bA sites along with the traditional knowledge of the elders may help us to refine our model and raise the model's prediction accuracy.

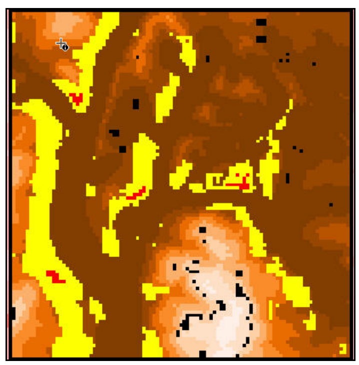

Figure 1. Map of Tobique First Nation and potential habitat sites suitable for growth and development of bA.

With global climate change, there is an urgent need to understand current forest species distribution, as climate change is anticipated to have profound effects on all of the earth's biota, as well as its distribution. Iverson and Prasad (2001) view predictive models that base habitat predictions on the evolution of environmental variables as suitable for climate-change scenario modeling. Prediction of species distribution is also seen as one of the requirements needed for effective sustainable management of forest resources, biodiversity conservation, and restoration (Dumortier et al. 2000; Martin 1977).

Conclusion

The habitat suitability model developed in this study predicted the occurrence of bA 84.6% of the time. The current model provides a level of accuracy sufficient to assist in the sustainable management and restoration of bA on Tobique First Nation land. The development and use of the current model may "open the door" for active restoration and management of bA throughout NB and perhaps the Atlantic provinces, and presents an opportunity to protect a traditional resource with cultural significance for many generations in the future. Further development and refinement of the modeling framework may equally "open the door" for the sustainable management of other tree species and medicinal plants not only on First Nation land, but on landholdings everywhere.

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Theme: Forest ecosystems

A national survey of community forests on public land in Canada

Teitelbaum, Sara[1]

Despite the popularity of the concept, there is relatively little empirical work on community forestry in Canada. This paper presents the results of a nation-wide survey of community forestry initiatives on public land. The survey focused on characteristics of community forests such as their objectives, organizational structures, tenure types and financial self-sufficiency. The research revealed that there are 100 initiatives that fall under our definition of community forestry, mainly in Ontario, Quebec and British Columbia. Close to half operate on Crown land while the other half operate on land owned fee simple by local government. The average age is 10 years and the median size of the land base is 4200 ha. Four different types of community forests were elucidated from the survey: local government on fee simple land, conservation authority, local government on Crown land, and forest organization.

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Theme: Forest management, operations and engineering

Modelling base cation fluxes and soil acid-base status in managed boreal stands in Quebec

Thiffault, Evelyne[1], Nicolas Bélanger[2], David Paré[3] and Alison D. Munson[4]

A dynamic biogeochemical model, SAFE, was applied to boreal stands in Québec to investigate the relative impacts of forest disturbances (clearcut, wildfire and spruce budworm outbreak) and atmospheric deposition on base cation fluxes and soil acid-base status. The three simulated sites were located in Haute-Mauricie, in the Basses-Laurentides and in Gaspésie. Soil base saturation was the parameter chosen for studying the soil status during the simulation period from 1700 to 2105. The model suggested that forest disturbances, both anthropogenic and natural, increased base saturation to different degrees for periods of one to five decades. However, such disturbances, no matter their interval of return and their intensity, did not appear to be the main driving force of soil chemistry in the long term. On the other hand, simulation results showed that the B horizons of all sites underwent acidification due to atmospheric deposition of nitrogen and sulphur during the 20th century. The site in Gaspésie, which lacks readily weatherable minerals such as plagioclase and hornblende, was the least protected against acid deposition. Simulating a stabilization of acid deposition from 2020 allowed sources and sinks of base cations to be in equilibrium in all sites until the end of the simulation period.

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Theme: Tree physiology, carbon and nutrient cycles and genetics

Gap dynamics of the eastern boreal forests using multi-temporal lidar data

Vepakomma, Udayalakshmi[1], Benoit St-Onge[2] and Daniel Kneeshaw[3]

Understanding any disturbance regime requires that we accurately characterize the disturbance itself spatially and temporally, especially where natural disturbance is used as a template for management practices. However, such properties can be complex to quantify over large spatial areas using field measurements. In this study, we analyze multi-temporal lidar data in conjunction with high-resolution optical remote sensing data over a 6 km^2 area to explicitly map, assess and precisely estimate the gap turnover rate of the eastern boreal forests within the non-spruce budworm infestation period. The interrelationships between the distribution of new gap openings within different stand types and ages are investigated. Influence of topography and proximity to a lake on species composition dynamics and gap characteristics is also studied. Total area under gaps decreased and 10% of the existing gaps expanded over the 5-year period. Rate of gap closure is higher than the gap opening with a gap turnover rate of 59 years for this forest. Nearly 93% of the openings are single or small groups of tree falls. Irrespective of the altitude, the proportion of both opening and closing of gaps decreased with increase in slope, and greatest proportion of them occurred in eastern and western positions.

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Theme: Forest ecosytems

Growth response from nitrogen fertilization of precommercially thinned spruce-fir stands

Wagner, Robert G.[1], Daniel J. McConville[2] and Russell D. Briggs[2]

We evaluated whether nitrogen (N) fertilization at 200 kg/ha (178 lbs/A) following precommercial thinning (PCT) increased the productivity of spruce-fir stands. Two fertilization studies (Weymouth Point and T-30) established in the mid-1990s were remeasured in 2003. These studies provided an opportunity to compare the effect of N fertilization shortly after PCT or waiting until stands were near crown closure. At Weymouth Point, where N fertilization occurred two years after PCT, no increase in volume growth from fertilization was found on three soil types. Results from the T-30 study, where N fertilization was delayed until crown closure (about 8 years after PCT), indicated that individual balsam fir had 82% higher volume growth in fertilized than unfertilized plots ($p = 0.0035$). Red spruce, however, showed no gain in individual tree volume growth ($p = 0.81$). When scaled up to the stand level, N fertilization of a pure balsam-fir stand with about 1,977 trees per ha (800 TPA) on these highly productive sites would produce an additional 6.1 m^3/ha/yr (1.1 cords/A/yr). If we assume that the stand is fertilized at year 20 (10 yrs after PCT), fertilizer costs \$247 US / ha (\$100 US /A), the stand can be harvested at year 40, and fir stumpage is going for \$162 US / m^3 (\$70 US / cord), the rate of return from N fertilization in this study was 10.7% and had a net present value of \$245 US / ha (\$99 US / A) (7% discount rate). This analysis assumed that we received the 6.1 m^3/ha/yr (1.1 cords/A/yr) growth increase for only 10 yrs after fertilization. Thus, a significant financial return appears to be possible with N fertilization of PCT balsam fir stands near crown closure on high productivity sites.

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Theme: Silviculture

Maine's Commercial Thinning Research Network

Wagner, Robert G.[1], Robert Seymour[1] and Spencer R. Meyer[2]

Maine's Commercial Thinning Research Network was established in 2000 to develop a better understanding about stand responses to commercial thinning in the state's forests. Initial efforts by the network included developing a set of interim guidelines for commercial thinning through the development of a software product called ThinME. The bulk of the effort has involved establishing a statewide network of research sites to address specific questions about commercial thinning. The Network consists of twelve study sites around Maine that represent spruce-fir stands in various stages of development, including precommercially thinned stands from 25-40 years old and non-spaced stands from 40-70 years old. Commercial thinning treatments were applied in factorial combinations of timing of first commercial entry (PCT stands) or type of commercial thinning (non-PCT stands) and level of relative density reduction. Regular post-treatment measurements are being collected from tagged trees to compare to the full pre-treatment inventory data. The Network has evolved to include several auxiliary studies that take advantage of the range of treatments available. These studies include research on growing space allocation, leaf area dynamics, physiological stress reactions to thinning, and the regeneration success of spruce and fir. Now with 5 years of post-treatment information, the Network has begun to provide answers to commercial thinning questions.

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Theme: Silviculture

Preliminary synthesis of threats and three-track importance for conservation planning in the transboundary northern Appalachians ecoregion

Woolmer, Gillian[1], Robert F. Baldwin[2], Steve Trombulak[3], Mark Anderson[4], Karen Beazley[5], Louise Gratton[6], Justina Ray[1] and Conrad Reining[7]

The Northern Appalachian/Acadian ecoregion is inclusive of the Adirondacks and stretches on both sides of the United States border through eastern Canada. Because of its jurisdictional complexity and land ownership patterns, it is a challenging ecoregion in which to effect systematic conservation planning. Therefore, an international group of scientists under the umbrella of 2C1Forest is conducting an analysis of threats and importance to inform large-scale conservation priorities, in particular the identification of at-risk linkage areas. Implementing a Human Footprint^{TM} methodology to map threats and developing multivariate models to project footprints into the future, combined with ongoing representation and focal species habitat needs assessment, the group is completing a synthesis. Human Footprint results indicate that currently only 16% of the ecoregion has low human influence, with 63% of remaining Northern Appalachian conservation opportunities in the State of Maine. Future Human Footprint results indicate threats accumulating through two distinct development processes (infilling of settled landscapes and development of wilderness areas). Scenarios project flat and moderately declining rural populations, but rapid exurbanization and amenity development resulting in increased isolation of remaining unsettled forests. Major landscape linkage priorities are in the Black River Valley (Tug Hill-Adirondacks), Lake Champlain Valley, Green-Sutton Mountains (VT-Quebec), Gaspé Peninsula-Maine, Chignectou Isthmus (NB-NS).

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Theme: Forest management, operations and engineering

Development of an integrated decision-support model for black spruce and jack pine stand density management in eastern Canada

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An integrated decision-support model has been developed for both black spruce and jack pine to assist forest managers in making stand density management and harvest decisions based on product recovery parameters instead of wood volume. The model included four components: 1) a stand-level growth model describing the relationship between stand density, tree growth and stand yield, 2) models describing stand-level DBH distributions in relation to commonly measured stand characteristics, 3) models describing the relationship between stem quality characteristics, and stand and tree characteristics, and 4) models describing the relationship of major product recovery parameters (e.g., lumber volume, chip volume, lumber value, and total product value) with tree/stand characteristics. Product recoveries of individual trees are linked to diameter distribution models to develop the stand-level decision-support systems for black spruce and jack pine stand management in eastern Canada. The models developed in this study allow for estimating the product recoveries of individual trees and of a forest stand before it is harvested. It is evident that the integrated decision-support models would be a valuable management tool for forest resource managers.

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Theme: Modeling, growth and yield

Abstracts from poster presentations

Note: the popular abstracts were not peer reviewed.

Relating blowdown to tree and stand level characteristics following a harvest resulting from an eastern spruce budworm (*Choristoneura fumiferana*) outbreak

Amos-Binks, Luke J.[1] and David A. MacLean[2]

Partial harvest prescriptions emulating natural disturbance can be susceptible to wind damage. Three areas totalling 2600 ha on the J.D. Irving, Ltd. Black Brook District in New Brunswick were treated with a harvest prescription resulting from an uncontrolled spruce budworm (*Choristoneura fumiferana*) outbreak, removing 9 out of 10 balsam fir and 6 out of 10 spruce. A network of permanent sample plots (PSPs), including controls, was installed prior to the harvest. Following harvest, blowdown began to occur, and in 2004 and 2005, trees in the PSPs were assigned to four damage classes: undamaged, uprooted, stem breakage, or crown damage. Untreated plots (39) sustained <1% (basal area) wind damage, versus an average of 15% in treated plots (47). Sixty-two percent of treated plots were in the 0-10% damage class, 17% sustained 11-30% damage, and the remaining 21% had damage >30%. Diameter at breast height and height were significantly smaller for stem-broken and uprooted trees compared with undamaged trees. Regression analyses comparing the percent blowdown basal area versus stand characteristics did not show significant relationships. Spatial arrangement of plots by blowdown category indicated some clustering of damage severity.

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Theme: Forest ecosystems

Developing New Brunswick's protected areas strategy: A case study comparing views of the most influential forest policy makers

Ashton, Bill[1]

How is forest policy developed? Relatively little research has focused on answering this question. Most often the answer refers to the rational model of steps from issue definition, to preferred solution, law making, implementation and evaluation. In contrast, policy research that touches all aspects of forestry draws upon many disciplines supported by scientific analysis. To begin to learn how forest policy is developed, I completed a case study of the New Brunswick protected areas strategy. This case study was based on ten in-depth interviews with the most influential policy makers from the three main stakeholder groups – provincial government, the forest industry, and environmental organizations. They form the new "iron triangle" of modern forest policy making. Using chronological analysis with background documents and recalled experiences of the policy makers, a timeline was constructed to compare and contrast their perceptions of six key moments. Despite the common perceptions among the three groups, and despite their working relationship for several years, their answers differed significantly about how this policy was developed. When taken together their answer had four parts: this forest policy was developed with 1) the decisive commitment of government, 2) the general involvement of the public and the specific participation of key stakeholder groups, 3) with an approach best described as disjointed incrementalism or ad hoc, 4) while making do with available resources. While this answer at one level differs significantly from the rational model, the steps were evident, but they held little sway over the policy makers' actions or perceptions. The three groups valued science to define the policy issue, but its role was limited thereafter. This presentation concludes with insight from the groups' perceptions on what constitutes good policy process and improvements when developing the protected areas strategy.

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Theme: Forest management, operations and engineering

TOPIQ database:
A tool to evaluate functional response of forest ecosystems to human disturbances

Aubin, Isabelle[1], Sophie Gachet[2], Christian Messier[3] and André Bouchard[4]

Recently, classification based on species biological traits or plant functional groups has been used as a framework for understanding ecosystem response to human disturbances. This approach facilitates the characterization of complex ecosystems and offers the possibility of inter-regional comparisons that could reveal patterns of organization that would be difficult to detect with a taxonomic approach. To construct plant functional groups, floristic survey data have to be linked to species ecological traits. Several databases of ecological traits exist around the world, but this type of database was not available for Québec flora. Thus, we developed TOPIQ (Traits of Plants in Québec), an ecological database containing information on plant morphology, dispersion, regeneration strategy and resource uptake of more than 400 vascular plant species of southern Québec. A total of 41 fields are documented, of which 23 are completed and validated. The TOPIQ database may be used to link traits to diverse environmental or field data tables. It offers new possibilities in the study of human impacts on vegetation processes. We present here a case study on the ecological value of plantations and another on the impact of human disturbances on sugar maple forests.

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Theme: Forest ecosystems

Investigating the role of contextual interactions in forest ecosystem response using experimental mesocosms

Blodgett, Corrie Alice[1], Deane Wang[2] and Carl Waite[2]

Within a natural community there exists a site-specific assemblage of abiotic and biotic factors that exhibit some degree of control over ecosystem response. These factors interact in ways that also contribute to ecosystem response. Ecosystem-level research studies often take place over large-scale and heterogeneous landscapes that encompass many of these site-specific or what can be called ‘contextual’ interactions. These interactions may be non-additive and therefore their influences are often not known. An experiment has been designed to study contextual interactions in young developing forest mesocosms located at the University of Vermont’s Wolcott Research Forest and the USDA Forest Service Aiken Laboratories in South Burlington, VT. Tree communities were harvested from the mesocosms in the summer of 2004. Preliminary analyses show that the site*soil interaction as expressed in nutrient export, as well as community main effects increase as the ecosystem increases its complexity. After the harvest, all interaction terms decrease in importance while community main effects have strong significance in determining variation in nutrient export. This may be interpreted to suggest that after the harvest, ecosystem response is largely controlled by nutrients leaching from roots. The importance of interactions may decrease due to the predominance of main effects in the simplified ecosystem after harvest.

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Theme: Forest ecosystems

Defects and indices of tree decay:
A stem classification guide for tree markers and forest managers

Boulet, Bruno[1]

The guide entitled *Défauts externes et indices de la carie des arbres – guide d'interprétation* is part of a project to update the 4th edition of Québec's Forest Management Manual (*Manuel d'aménagement forestier*). This is needed in light of research carried out and knowledge obtained since 1998, to improve the practice of selection harvesting in uneven-aged hardwood forests on Québec's public lands. This is a didactic publication that is the result of ongoing collaboration among numerous stakeholders in industry and the *ministère des Ressources naturelles et de la faune*. It is the recommended reference for meeting the requirements of the Tree Markers' Professional Recognition Program (*Programme de reconnaissance professionnelle des marteleurs au Québec*). It offers foresters, technicians and forest rangers a stringent diagnostic method for identifying tree defects, evaluating them with respect to the tree's future vigour and to then rank them in terms of their harvesting priority, as needed. It includes the fundamentals of forest pathology and all the tools needed to learn to identify and rank trees that will be lost from dying or degenerating in the more or less short term. Also discussed are other anomalies affecting the roots, the stem and the crown that do not have a debilitating effect on tree vigour or wood quality in the long term.

In practice, this information is a prerequisite for detecting the early-warning signs and symptoms of diseases, and for making a precise diagnosis of each stem in the stand. The state of health of all the trees can then be objectively evaluated in order to differentiate, before cutting, the weak or sick trees that are most affected from the other vigorous trees that need to be released and maintained as crop trees. This new tree classification method permits us to collect data that is reliable, verifiable and very useful in the planning stages, as well as for actually carrying out partial cuts in hardwood or mixedwood stands. It can also be of great help to the manager desirous of producing high-quality lumber or to the sugar bush operator wanting to improve syrup production.

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Theme: Silviculture

Relationships between nonnative invasive plant distribution, silvicultural treatment and soil drainage in the northern conifer forest

Bryce, Elizabeth[1], Laura Kenefic[2], Alison Dibble[3], John Brissette[2] and William Livingston[1]

Because anthropogenic disturbances may favor the encroachment of nonnative invasive plant species, forest managers are concerned about protecting the integrity of forest ecosystems. To address this concern, the relationships between nonnative invasive plant density, soil drainage, and harvest type and intensity are being investigated in the mixed conifer forest of northern New England. Our study area is the USDA Forest Service, Northern Research Station's long-term silvicultural experiment on the Penobscot Experimental Forest (PEF) in Maine. Twenty stands representing ten silvicultural treatments will be sampled. Nonnative invasive species such as purple loosestrife (*Lythrum salicaria*), and shrub honeysuckles (*Lonicera* spp.) have been found within the PEF boundaries; a complete assessment of the understory vegetation will be made after the completion of sampling. We anticipate that our findings will provide important baseline data, facilitate silvicultural recommendations and provide a basis for future research on nonnative invasive plants in this forest type.

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Theme: Silviculture

Using site and climate variables to explain forest productivity in Nova Scotia

Clowater, Christopher W.[1], Charles P.-A. Bourque[2], Fan-Rui Meng[2] and Edwin Swift[3]

Understanding the ecological processes that govern forest development over time and predicting future stand growth and yield from these processes are one of the primary challenges in forest management planning. Tree growth is controlled by solar radiation, water availability, nutrient availability and site variables such as temperature and precipitation. Decision making and planning in forests of variable land and forest conditions, such as those in Nova Scotia, require methods of estimating forest site productivity for each of the important tree species. Therefore, the objective of this paper is to determine the degree to which the five main environmental variables (i.e. solar radiation, soil fertility, soil drainage, temperature and precipitation) explain variation in tree and stand growth in Nova Scotia. Potential forest productivity maps will be created for each of the main environmental variables, showing potential productivity classes from "very low" to "high". Significant differences in the growth rate relationships will be used to refine the individual environmental variable maps. A site quality map based on the five potential productivity maps may provide a useful means for estimating site potential as a basis for silvicultural and sustainable forest management decisions.

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Theme: Modeling, growth and yield

Tree level diversity:
Do tree-level monocultures develop after canadian boreal silviculture?

Dampier, Jason, E.E.[1], Nancy Luckai[1], F. Wayne Bell[3], and William D. Towill[4]

Concern about vegetation management practices reducing tree-level diversity and creating tree-level monoculture plantations exists. Our study investigated tree-level responses for six early seral boreal forest trials in Ontario, Canada, utilizing three commercially important conifer species; black spruce [*Picea mariana* (Mill) B.S.P.], white spruce [*Picea glauca* (Moench) Voss] and jack pine (*Pinus banksiana* Lamb.), 13 release treatments (plus untreated controls) and 91 experimental units (∑ *replications x treatments by site*). Dominance-diversity curves and Simpson's indices of diversity and evenness were used to indicate tree alpha diversity. In addition, we proposed a new method for assessing diversity - percentage of theoretical species maximum (%TSM). This metric, which has the advantage of incorporating pre-disturbance information, compares post-disturbance richness (S) with a theoretical species maximum (TSM). Data generated was also appropriate for Analysis of Variance (testing for overall treatment effects) and *a priori* contrasts (Control *vs*. Individual Treatments). Our hypotheses were 1) alternative vegetation release treatments do not reduce tree-diversity level relative to untreated plots (in other words $u_1 = u_2 = u_3$, etc) and 2) tree monocultures do not develop after typical vegetation release. Results indicate that there was insufficient evidence to reject either hypothesis. The only comparison that produced a %TSM treatment diversity less than Control was Repeated Annual Applications of Vision (CRV) herbicide at one of the black spruce study sites (Sb3). The same treatment package (CRV) at another spruce site (Sb2) produced the only experimental unit (out of a total of 91 e.u.) that developed into a tree layer monoculture (Simpson's reciprocal diversity index = 1). Repeated Annual Applications of any herbicide is not a typical vegetation management alternative and was included in the experiments to provide an extreme treatment for comparison purposes only. Nonetheless, within the context of desired future forest conditions, tree-level monocultures may be one of several ecologically defensible objectives given the natural range of variability at the landscape level. Our conclusion overall is that typical vegetation management practices in northern Ontario's boreal forests do not result in a reduction of tree-level diversity.

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Theme: Forest management, operations and engineering

Comparing site characteristics and hemlock recovery potential to a model of hemlock decline at the northern range of the hemlock woolly adelgid infestation

DeMaio, Sophia[1] and William H. Livingston[2]

The hemlock woolly adelgid (HWA) is established in the southern tip of Maine, but state quarantine on hemlock trees and products combined with direct controls should allow time for preemptive planning and management of hemlock stands to deal with the future spread of the insect. A potential tool for guiding future management decisions is a mathematical model developed by Jennifer Pontius (USFS, Durham, NH) that quantifies the relationship between site, climate, and soil chemistry to HWA incited decline. In addition to the known relationships between HWA decline and site, infested hemlocks suffering from additional stresses are most likely to decline and die. We will examine the relationship between the predictive model and site variables with the ability of hemlock to recover from a second stress, drought. Dendrochronological methods will be used to evaluate a tree's ability to recover from drought conditions that occurred in southern Maine in both 1995 and 2001. In the center of each of up to 30 sample plots (fifth acre), site characteristics (slope, aspect, soil type) will be measured, and twelve dominant/co-dominant hemlocks will be measured for vigor (% dieback, live crown ratio) and cored. Recovery from drought will be measured by quantifying the percent growth increase after drought events. Correlations between % growth increase after drought, tree vigor, site parameters, and HWA risk rating will be evaluated.

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Theme: Modeling, growth and yield

A second generation of genetically improved trees for the boreal forest in Quebec

Desponts, Mireille[1] and R. Beaudoin[2]

Black spruce and jack pine are the most important species for reforestation in the boreal zone. More than 100 million seedlings are planted annually, mostly in the northern boreal zone. Despite less favourable growth conditions, the extra volume obtained by reforestation using improved material is not negligible given the size of the territory and the number of seedlings planted. Over the last 30 years, one million seedlings from open-pollinated families have been tested in 81 progeny tests distributed within 5 breeding zones for each species. Thirty-six first-generation seed orchards have been established and rogued at 10 years of age. Superior trees were selected based on height growth, stem straightness and branching characteristics, and are now being used in control crosses to produce material for the next generation. They were also propagated by cuttings (black spruce) or grafts (jack pine) and clonal seed orchards were established in the past few years. Genetic gains in volume by using genetically improved seeds are estimated to be 9 m^3/ha at 40 years of age for jack pine and to be 15 to 20 m^3/ha at 35 years of age for black spruce, compared with natural stand collections.

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Theme: Tree physiology, carbon and nutrient cycles and genetics

Assessing uncertainty of growth predictions for a single tree-based stand growth simulator

Fortin, Mathieu[1], Josianne DeBlois[2] and Steve Bédard[2]

SaMARE is a growth simulator for hardwood stands under uneven-aged management in southern Quebec. It is based on a single-tree, distance-independent approach. By simulating error components for the submodels that compose SaMARE, it is possible to generate stand growth predictions and their errors. This process is referred to as Monte Carlo simulation. In this presentation, we address some issues related to the reliability of Monte Carlo-simulated predictions and errors.

Permanent-plot data were used to simulate stand growth over a 15-year period. Predictions were first compared with observed values in order to assess the biases and the standard errors. The accuracy of the simulated prediction errors was then assessed through a rank analysis.

The results showed that the biases were small in absolute values, but could be high in relative values for some stand attributes. The simulated prediction errors covered most of the observed values, and there was no evidence of departure from the simulated error distribution. All things considered, SaMARE is thought to provide a reliable estimate of prediction uncertainty.

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Theme: Modeling, growth, and yield

Zoning riparian areas and hydrosystems using an approach inspired by the triad

Gagnon, Patricia[1,2] and Marcel Darveau[2,3]

The boreal forest represents an immense richness in terms of terrestrial ecosystems, but also hydrosystems through a complex network of lakes, rivers, and wetlands. Because many wildlife species use and often depend on both terrestrial and aquatic habitats for their life cycle, most of them are likely to use riparian habitats. In addition to this high biological importance, riparian habitats are used by humans for a variety of activities, including hydroelectricity, cottage resorts, and ecotourism. Although several scientific works have proposed management principles for these areas, there are few examples of their implementation, except perhaps for best forest management practices. A problem with these best practices is that forest management efforts could be lost if we do not insure that other users do not mitigate the efforts of foresters by converting the areas protected from harvest into resorts or other conflicting uses. A solution to this problem could be to zone using an approach inspired by the triad. This means three different land use categories: protected ecosystems, intensive human use areas, and multi-functional areas under ecosystemic management. We tested that approach at the Forêt Montmorency (Quebec), a 67-km² teaching, demonstration, and research forest under the responsibility of Université Laval. Our results revealed, among others, that in this hilly landscape where hydrosystems are rare (2.4%), there is high pressure on riparian areas, but zoning can easily be implemented.

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Theme: Wildlife

Beech mortality and drought in Maine

Kasson, Matthew[1], William H. Livingston[2] and David Struble[3]

In northern Maine, inventory plots measured from 1999-2002 showed an average cumulative mortality of beech (*Fagus grandifolia*) reaching 13% since 1995 in stands with ≥ 20 ft^2 of basal area per acre. Inventory plots measured from 2003-2004 showed an average cumulative mortality of 44% since 1995. The purpose of this study is to investigate potential factors influencing this increase in mortality. Initial observations indicate two types of stands. The first type involves stands affected in the 1930's by beech bark disease and are now "aftermath" forests of beech sprouts. These stands are now reaching a size and age at which beech bark disease probably contributes to the observed increase in mortality, especially after the drought of 2001. The second type of stand involves those in northern Maine that show significant mortality but no previous symptoms of beech bark disease. The drought in 2001 and/or an outbreak of beech scale (*Cryptococcus fagisuga*) associated with warmer winters may have predisposed these trees to infection and mortality by a *Nectria* fungus. To investigate the interactions among all of the above factors, paired plots in 11 townships were sampled during the summer of 2005 in northern Maine. Initial results indicate that both *Nectria galligena* and *Nectria coccinea* var. *faginata* are involved in killing the trees. Future work includes tree-ring analysis, statistical analysis of site factors, and sampling additional plots in 2006.

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Theme: Forest ecosystems

Calibration and validation of the Forest Vegetation Simulator (FVS) using historical data for boreal species in Ontario

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There is a long history of development and application of the Forest Vegetation Simulator (FVS) for the prediction of the growth and yield of several forest types in North America. Historical data originating from permanent sample plots located in different regions of northern Ontario were used to derive new models for the prediction of dbh growth rate, survival rate, stem height and species group density index for black spruce (*Picea mariana* (Mill.) B.S.P.), jack pine (*Pinus banksiana* Lamb.), balsam fir (*Abies balsamea* (L.) Mill.) and trembling aspen (*Populus tremuloides* Michx.). This dataset was characterized by large variations in age, stand density and site index. The new species-specific models were then integrated within the source code of FVS to replace the original models of the Lake States variant of FVS. A validation exercise was conducted by comparing the accuracy and biological consistency of the new models with the original models of the Lake States variant of FVS. An independent dataset consisting of remeasured permanent sample plot data maintained by the ministère des Ressources naturelles et de la Faune du Québec was also used for the validation exercise. Results indicated that the new models had significantly lower mean residuals than the original FVS models. The biological consistency analysis indicated that the new models predicted logically tree growth and survival. There was a pattern of increase in predicted dbh growth rate with increase in stem dbh, mean stand dbh and site index, and a pattern of decrease with increase in basal area. Predicted survival rate increased with dbh growth rate and stem dbh, but decreased with increase in basal area of the trees larger than the subject tree.

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Theme: Modeling, growth and yield

Determinants of forest fire suppression costs in New Brunswick

Lantz, Van A.[1] and Greg Slaney[2]

Over the past decade, there have been over 2500 forest fires in New Brunswick. The cost of suppressing each fire has varied considerably, ranging from a few hundred dollars to half a million. While forest fires that have been less than 1 ha represent over 90% of the total fires, they only represented 25% of suppression costs. This observation emphasizes the role that fire size plays in determining fire suppression costs. However, fire size is only one of the many variables thought to affect suppression costs. Other variables, such as the type of suppression equipment used, the response timing of the suppression team, the duration of the fire, and weather conditions can have a profound effect on suppression costs. This study employs regression analysis to investigate the influence that such variables have on forest fire suppression costs. Using fire suppression data for New Brunswick over the period 1987-1996, the analysis indicates that fire size, fire duration, and the use of aircraft have the largest impact on suppression costs. The fire size-cost relationship in particular is found to be highly non-linear, indicating the presence of economies of scale.

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Theme: Forest management, operations and engineering

Updating northern Maine land cover data using satellite-based change detection techniques

Legaard, Kasey, R.[1], Erin M. Simons[2] and Steven A. Sader[3]

Harvest patterns in Maine's commercial forests have been heavily impacted by recent changes in forest policy and ownership. These changes are likely to affect the future stability of Maine's forest resources and the sustainability of wildlife species that depend on early-successional or intact mature forest. It is increasingly important that we understand the long-term effects of forest management on landscape patterns and processes. To this end, we have developed a means through which older land cover products can be updated to present conditions using satellite-based change detection techniques. We demonstrate our approach by producing a 2004 land cover map of northern Maine created by updating the 1993 Maine GAP land cover map to reflect harvest activity detected using intervening Landsat imagery. A direct comparison of 1993 and 2004 land cover data documents the cumulative effect of changes in harvest patterns. By exploiting existing land cover products, our approach offers a flexible and cost effective means for producing up-to-date land cover data needed to identify and evaluate landscape change.

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Theme: Forest management, operations and engineering

The effect of competition on individual tree basal area growth in mature stands of *Picea mariana* in northern Québec

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In this study, we wanted to compare the performance of distance-independent, distance-dependent and light-based competition indices in predicting individual tree basal area growth in mature stands of *Picea mariana* in northern Québec. The predictability of individual tree growth rates was related to crown dimensions and other stand and tree variables measured in the field. A three-dimensional light model was also used to calculate light-based competition indices. Growth data were collected from more than 1200 trees measured in eight stands of varying site qualities (range 12.6–16.7 m height at 50 years) and age (range 68–80 years). The mean square error reduction relative to no competition was used to evaluate the performance of each competition index. It was found that the distance-dependent and light-based competition indices performed slightly better than the distance-independent indices. The HEGYI distance-dependent index and a light-based competition index were found to be potential indices that could be incorporated into further individual tree basal area growth models for this species in the study area.

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Theme: Modeling, growth and yield

Long-term responses of the herbaceous layer to different harvesting disturbances

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Abstract

We examined the abundance patterns of herbaceous species before harvest (1995) and several years after harvest (1996, 1997, 1999, and 2004) in two treatments (clearcutting followed by natural regeneration, C; and clearcutting followed by mechanical site preparation and planting, CS) and two unharvested controls (riparian buffer strip, BU; and upland forest, UC). The long-term changes of the herbaceous layer in composition and structure were studied in relation to the severity of disturbance. Changes in reproduction strategy were also examined in C and CS treatments compared with unharvested controls. The CS treatment showed more dramatic changes in the patterns of species abundance than the C treatment, due to the greater forest floor disturbance caused by site preparation. The number of residual species (species which existed before disturbance) declined from 76 in 1995 to 55 in 2004 in the CS treatment and from 58 to 54 in the C treatment. Twenty nine new species invaded the CS sites and 24 invaded the C sites during the study period.

Introduction

Numerous studies have examined species abundance patterns and mechanisms of successional changes in the forest understory. Peet and Christensen (1988) have hypothesized that changes in competition during stand development cause changes in species diversity. Halpern and Spies (1995) suggested that there are initial effects and long-term effects of disturbance on plant communities. Initial effects influence existing plant populations through propagule availability, modification of habitats and species invasion (Gilliam and Roberts 2003). Long-term effects include competitive relationships, increases in spatial heterogeneity, and changes in species composition (Spies 1991; Gilliam and Roberts 2003). However, little is known about changes in dynamics of the herbaceous layer with time, due to the lack of long-term studies (Gilliam and Roberts 2003). In particular, it is necessary to assess the long-term effects of different disturbance severities on species patterns for the purpose of forest conservation and management. The main goal of this project is to determine the effects of different disturbance severities resulting from forest harvesting on herbaceous layer composition and structure over 10

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years and to examine why the general floristic changes occurred in terms of life history traits of the species and disturbance characteristics. The objectives are to: 1) determine changes in composition and structure in the forest understory in relation to the severity of disturbance; 2) determine relationships between disturbance characteristics and species abundance patterns; and 3) determine interactions between different disturbance severities and life history characteristics of the species.

Method

The study was conducted within a small (56ha) watershed with predominantly NW and SE aspects in southern New Brunswick, Canada (Zhu 2002). We collected data in 161 permanent plots ($5m^2$) before harvesting and 9 years after in two harvesting treatments (clearcutting followed by natural regeneration, C: 63 plots; and clearcutting followed by mechanical site preparation and planting, CS: 43 plots) and two unharvested controls (riparian buffer strip, BU: 14 plots; and upland forest, UC: 41 plots). Plots were placed on transects which started in the riparian buffer strip. The spacing was 50m between plots and approximately 50m between transects (Zhu 2002).

All variables were measured on each quadrat before and after harvesting. To sample the herbaceous layer (all plants < 1 m tall), percent covers of each vascular species were estimated visually. To quantify the disturbance conditions, percent cover of disturbance variables (canopy, slash coverage, living slash coverage, substrate and tracks) were also estimated (Zhu 2002).

Results and discussion

Compositional changes in forest understory

The number of invading species (species which did not appear in the predisturbance plots) increased rapidly in the fourth year following disturbance in C and CS treatments and remained predominant in the final year of sampling (Figure 1A). The richness of BU and UC treatments increased slowly (Figure 1A). While the species richness of residual species (species which already existed in the predisturbance plots) declined in all treatments over the study period (Figure 1B): Species richness decreased from 53 species in 1995 to 39 in 2004 in BU; from 58 to 54 in C; from 76 to 55 in CS; and from 47 to 43 in UC, the greatest reduction in species richness occurred The BU and CS treatments showed the most declines in richness.

Structural changes in forest understory

The canopy cover of invading low-shrubs (*Rubus allegheniensis, Rubus idaeus, and Diervilla lonicera*) expanded dramatically in both C and CS treatments (Figures 2A and B). Total canopy cover of a few dominant residual species, including herbs (*Cornus canadensis* and *Maianthemum canadense*); ferns (*Equisetum spp* and *Pteridium aquilinum*), and sub-shrubs (*Gaultheria procumbens*) also expanded rapidly in C and CS treatments, however, canopy cover of residual trees (*Abies balsamea* and *Picea rubens*) and tall-shrubs (*Hamamelis virginiana* and *Amelanchier spp*) recovered slowly (Figures 2C and D).

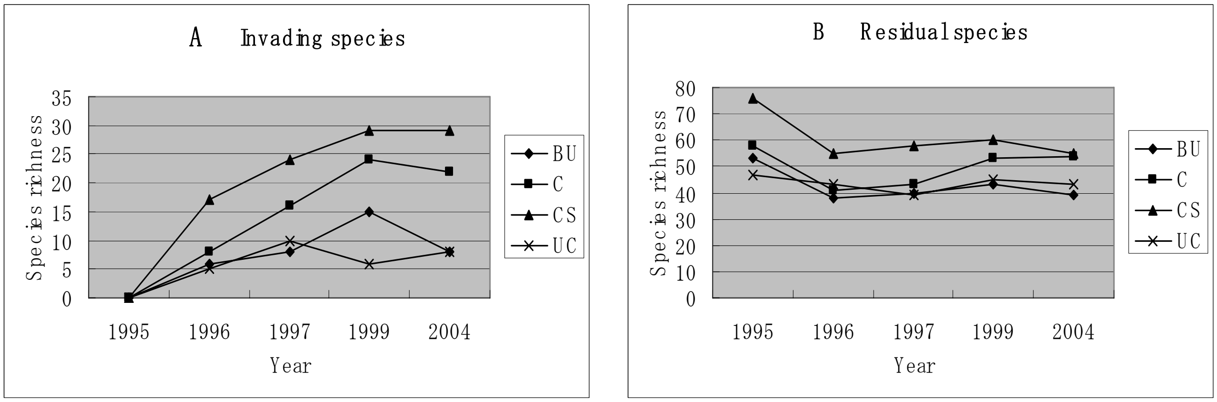

Figure 1. Changes in total species richness with time in four treatments for the invading species (A) and residual species (B).

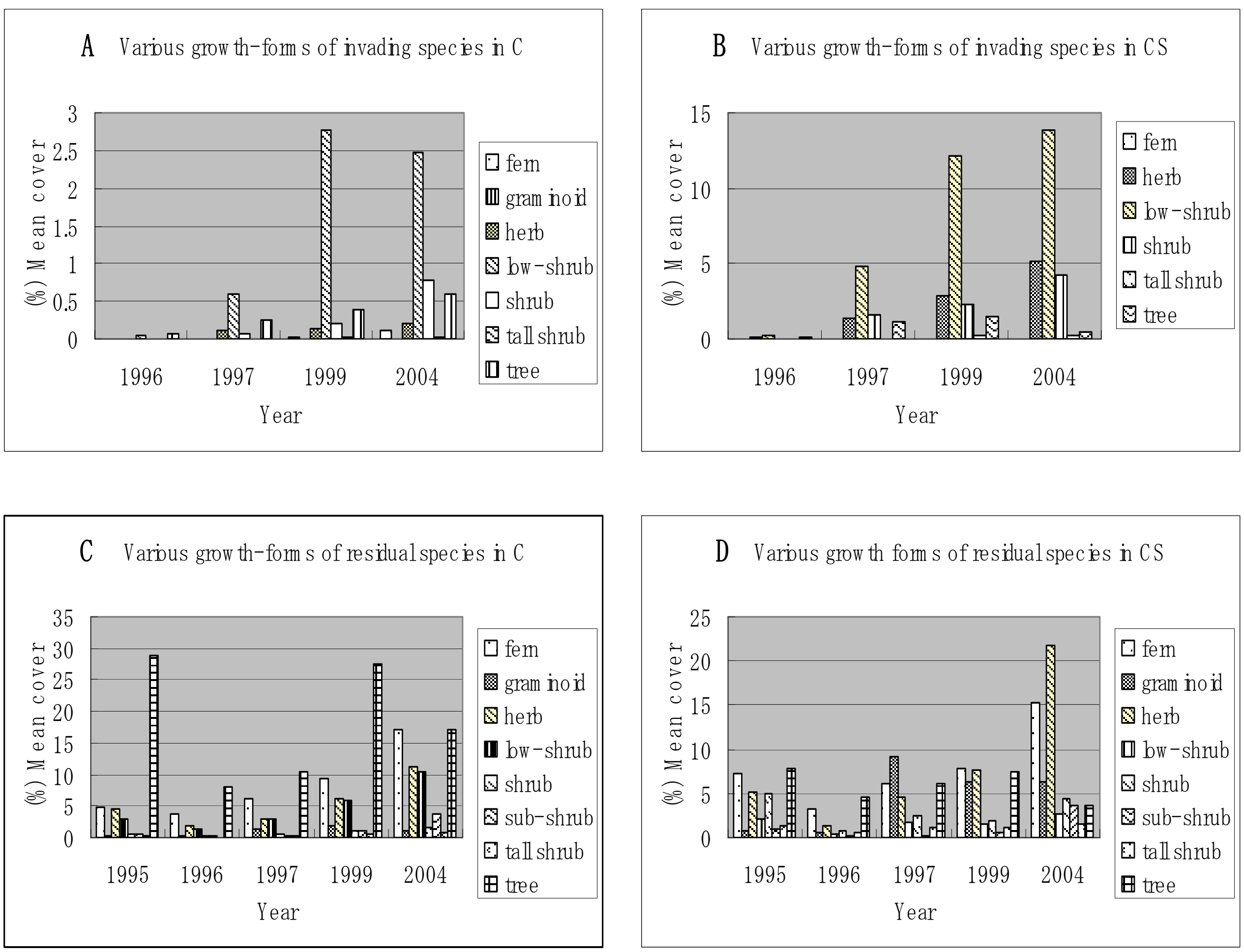

Figure 2. Changes in total mean cover with time based on growth-forms for the invading species in C (A) and in CS (B) as well as the residual species in C (C) and in CS (D).

Reproduction strategies and species recovery

Species with animal and wind dispersed seeds increased in both C and CS treatments (Figure 3B and C). This is due to increases of species with palatable fruits as well as of weedy species with light, easily blown seeds. The number of vegetative species, on the other hand, declined in BU (Figure 3A) and CS treatments. These species were mainly disturbance-sensitive species. This may be due to edge effects in BU and the ground disturbance in CS, caused by scarification. The UC treatment did not show any major changes during the study period (Figure 3D).

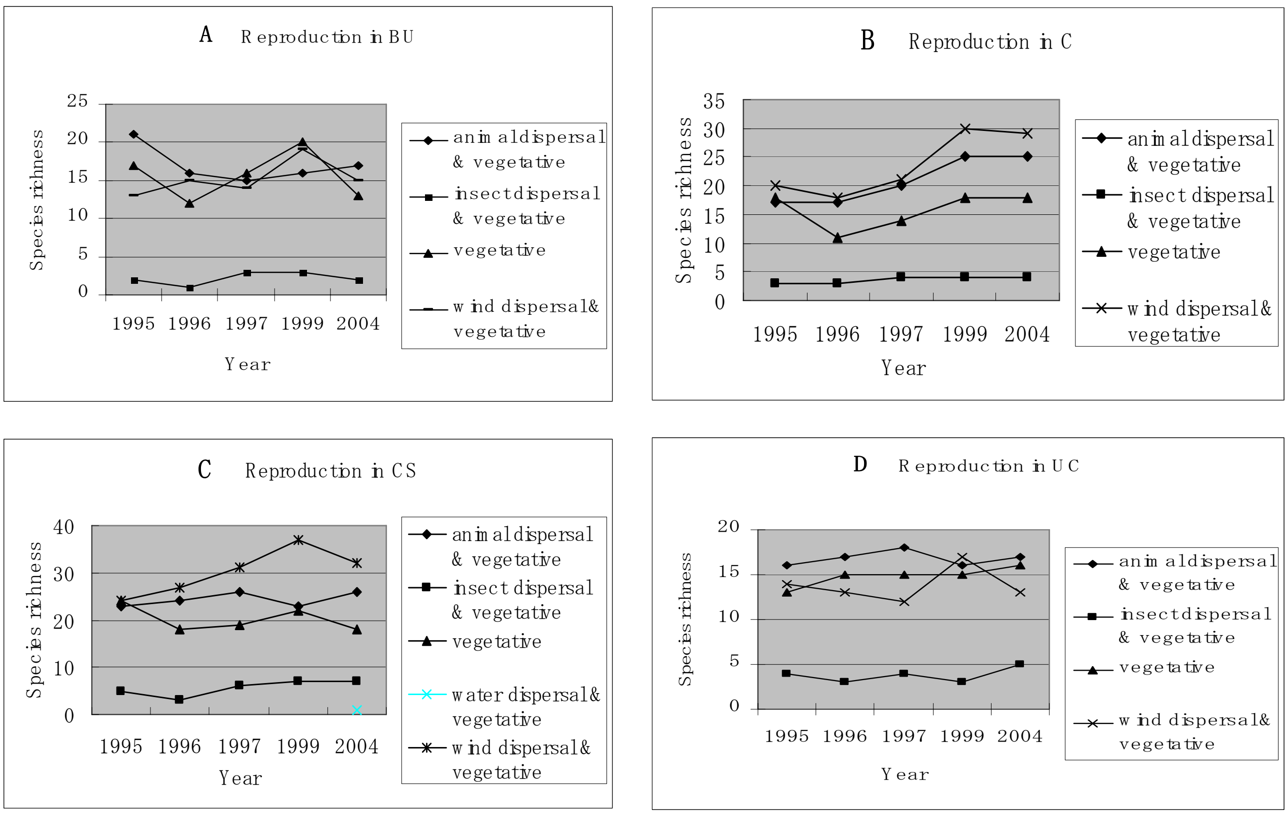

Figure 3. Changes in species richness with time based on reproduction strategies in BU (A), C (B), CS (C), and UC (D).

Conclusion

The higher disturbance severities (CS) showed the greater impact on the herbaceous layer. First, abundance of a few dominant species expanded in C and CS treatments over the study period. These species were invading low-shrubs, and residual herbs, ferns, and sub-shrubs. Second, species richness of invading species peaked rapidly in the fourth year after disturbance and remained predominant. The species that increased were those with animal and wind dispersed seeds. The richness of residual species, on the other hand, declined on all treatments throughout the study period. The CS treatment, in particular, showed the greatest decline in species richness, due to a reduction of vegetatively reproducing species that require woods or wet sites as habitat. Reducing the use of site preparation could minimize disturbance to the forest understory and prevent the loss of disturbance-sensitive species.

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Theme: Silviculture

Liming stops decline and increases growth of sugar maple

Moore, Jean-David[1] and Rock Ouimet

Complete article can be found at: Moore, J.-D. et Ouimet, R. 2006. Ten-years effect of dolomitic lime on the nutrition, crown vigor and growth of sugar maple. Can. J. For. Res. 36: 1834-1841.

Introduction

Although the majority of northern hardwood forests recovered from forest dieback that occurred in the 1980s, the health of sugar maple forests remains a major concern in some areas, including Pennsylvania and Vermont in the USA, and Québec and Ontario in Canada. Several hypotheses have been reported relative to sugar maple dieback, including acid deposition, insect defoliation, and extreme climatic events. Studies conducted at the Duchesnay Experimental forest showed that acid deposition has contributed to the loss of available Ca from acid and base-poor forest soils, which could induced the sugar maple decline phenomenon and growth reduction.

The goal of this study was 1) to link soil Ca-deficiency to sugar maple growth reduction and decline as a result of a liming experiment, and 2) to document the mid-term (10 years) maple response to this treatment.

Method

The Duchesnay Experimental forest (50 km northwest of Québec) is characterized by a very acid and base-poor soil. Moreover, sugar maples in this area have a high crown dieback rate. At Duchesnay, 98 sugar maple trees were selected, numbered and lime ($CaMg(CO3)2$) randomly applied in fall of 1994 (14 replicates for controls and 12 for the seven other treatments). Lime spreading was done manually within a 5-m radius of each tree. Eight lime treatments were applied (0, 0.5, 1, 2, 5, 10, 20 and 50 $t \cdot ha^{-1}$).

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Discussion

One decade after treatment, foliar Ca and Mg concentrations of sugar maple were still higher for treated as compared to control trees. Since 1994, liming stopped the progression of decline symptoms for treated sugar maple trees whereas dieback increased four times for unlimed trees (Figure 1).

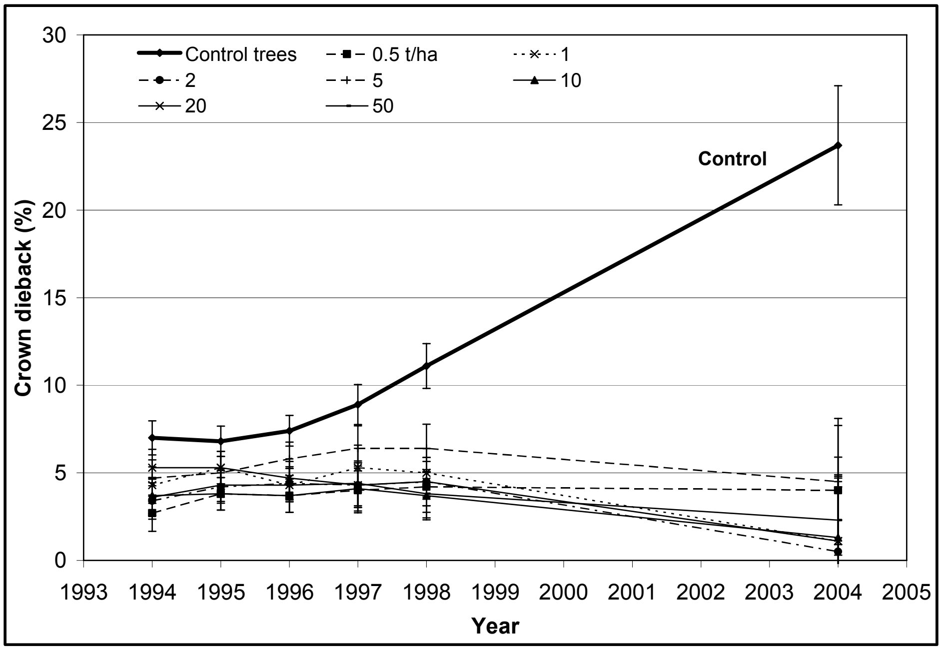

Figure 1. Crown dieback of sugar maple at Duchesnay before and during the 10 years following liming. Bars represent ± 2 SE.

Also, during the first ten years after liming, basal area increment for limed sugar maple trees was nearly twice higher than the one of unlimed trees (Figure 2).

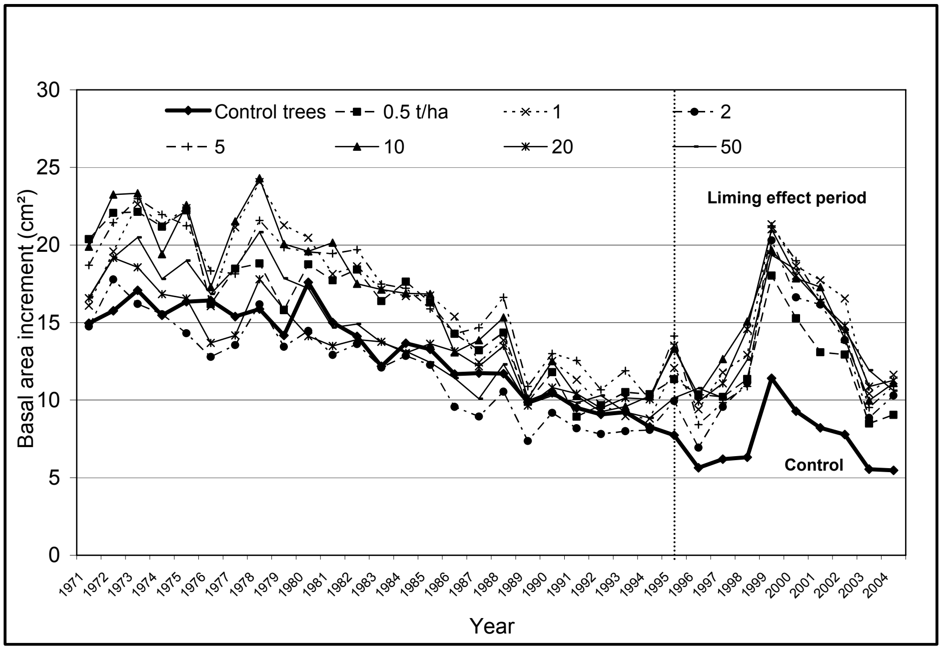

Figure 2. Growth of sugar maple at Duchesnay before and during the 10 years following liming.

Conclusion

Mid-term efficacy of liming in this study was demonstrated by the improvement of sugar maple Ca nutrition, crown vigor and stem growth. This confirms the potential of liming to reverse the course of the maple decline phenomenon and growth reduction at Duchesnay caused by acid deposition.

Acknowledgements

We wish to thank Claude Camiré of Université Laval, who supervised the experimental implementation, Benoît Toussaint and Jacques Martineau for field assistance, and Louis Blais for statistical advice.

Theme: Tree physiology, carbon and nutrient cycles and genetics

A comparative assessment of harvesting outcomes on eastern US non-industrial private forestland

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Defined as forestland that is privately owned by individuals or corporations other than the forest industry, non-industrial private forestland (NIPF) is an ever more important form of forest ownership in the Eastern US both from a spatial and timber management perspective. This is particularly true in light of divested private industrial forests and marked reductions in public forestland harvests nationally. In light of these trends, we conducted research to help improve our understanding of NIPF management by measuring how harvesting outcomes vary in different management settings and forest types. Forest conditions were uniformly measured on harvested southern pine forests in the north central hills of Mississippi and northern hardwood forests in the Catskill Mountains of southeastern New York. Fixed-area 1/10th acre plots were used to measure residual stems and stumps on harvests conducted in the past 5 years. Residual stems were measured and assessed for quality and merchantable potential. The diameter and species of all recent stumps were also recorded. Results of these measurements are used to discuss similarities and differences in harvesting outcomes between both regions, ultimately improving our understanding of NIPF management and its variability across pertinent management and biophysical spectra.

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Theme: Forest management, operations and engineering

Acadian Forest Ecosystem Research Program: Studying the effects of expanding gap silviculture

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The Acadian Forest Ecosystem Research Program (AFERP) was initiated in 1993 on the Penobscot Experiment Forest in Bradley, Maine. AFERP is comparing two expanding-gap treatments designed to mimic the 1% natural disturbance frequency common within the Acadian ecoregion: (1) 20% removal on a 10-year cutting cycle, a 10-year regeneration window between expansions, and a 50-year rest period following the first five cycles; (2) 10% removal on a 10-year cutting cycle, 20-year regeneration window between expansions, and no rest period; and an unharvested control. A dispersed network of permanent reserve trees, equaling 10% of the basal area, is being maintained in both treatments. Experimental units are roughly 10 ha and replicated three times in a randomized block design. The study has provided a template for examining a variety of ecological questions related to gap disturbances. Gap harvesting influenced the volume of downed woody debris (DWD), and increased vegetation abundance and diversity relative to natural gaps and undisturbed canopy. Although avian communities were largely unaffected by the initial gap openings, amphibian and arthropod communities showed variable species-specific responses. A recent analysis on financial returns from harvesting indicates that the expanding-gap method is a viable system for small woodland owners.

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Theme: Silviculture

Quality and productivity of our future hybrid larch: Spin-offs from 35 years of larch breeding at the MRNF-Québec

Perron, Martin[1]

In 2005, the MRNF (ministère des Ressources naturelles et de la Faune) reached an important milestone for implementing intensive silviculture in Québec. The 40 best larch parents (20 *Larix decidua* [**EL**] and 20 *L. kaempferi* [**JL**]) were identified among over 40,000 candidate trees. Interspecific control crosses among these trees will produce seeds of our new improved variety of hybrid larch. Estimates in genetic gains for trunk straightness (**TS**) and merchantable volume (**MV**) were made independently for both parent species. For the 20 EL, 93% of their progeny should achieve an acceptable TS (straight or slightly crooked) at approximately age 12, while it should reach 62% for the 20 JL at age 9. For the 20 EL progenies, expected gain in MV represents an increase of 14% at a spacing of 2 m x 3 m, at 30 years (30 m^3/ha), compared with the weighted mean obtained from the tests used for the selection. For the 20 JL, this gain is estimated at 7% at 30 years (17 m^3/ha). In conclusion, these genetic gains will assure the quality of our new hybrid larch variety for operational planting.

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Theme: Tree physiology, carbon and nutrient cycles and genetics

From seeds to plantation: Thirty years of research development at the operational level to improve white spruce productivity

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In Québec, approximately 135 million seedlings are planted annually. One particularity of the reforestation program is that the provincial government has the responsibility for producing both seeds and seedlings, delimiting seed zones and establishing transfer rules. This situation creates a unique opportunity for rapid transfer of research advances to the operational scale. Due to its superior growth and wood quality, white spruce is one of the most important species for reforestation; approximately 25 million seedlings are planted annually, of which 85% are grown from genetically improved seeds. By capitalizing on the knowledge and material gained from more than 30 years of tree improvement, seed orchard management, nursery cultural practices and tree seedling production through rooted cuttings and somatic embryogenesis, Québec is in a position to increase its forest productivity by reforesting with improved material. New tools are also being developed to support operational research, such as molecular studies, which will help tree improvers carry out selections, or combined models to estimate the impact of climate change on seed zones as well as on plantation yield. Plantation of improved material will not only reduce the increasing pressure on natural forests, but also play a determining role in the face of environmental, economic and social issues.

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Theme: Tree physiology, carbon and nutrient cycles and genetics

Planted white pine and white spruce performance under various overstory retention levels in a high-graded mixedwood stand

Roy, Vincent[1] and Marcel Prévost[1]

Introduction

Overstory retention in silvicultural systems is increasingly carried out in eastern Canada to maintain or restore ecological functions and biodiversity values in managed forests. In high-graded mixedwood stands, planting under residual cover can restore species composition. However, overstory and understory vegetation management will be necessary to create favourable microclimate conditions for seedling establishment and development.

Material and methods

The present study is part of a larger experiment, established in 2001, to compare combinations of silvicultural treatments for restoring degraded irregular mixedwood stands through both natural and artificial regeneration. In this poster, we present results from the plantation trial only.

We selected an experimental area (47°49' N, 72°36' W) in the balsam fir-yellow birch bioclimatic domain of the Province of Québec that had been partially harvested with a diameter limit-cutting in 1988. The resulting stand in 2001 was a patchy and irregular mixture of trees of low value. Overstory was dominated by poorly formed yellow birch (*Betula alleghaniensis*) and balsam fir (*Abies balsamea*) residual stems. The average density and basal area of merchantable stems was 487 stems/ha and 11.5 m^2 ha^{-1}, respectively. Aggressive competing vegetation invasion of the understory resulted in 5700 saplings/ha of mountain maple (*Acer spicatum*) and pin cherry (*Prunus pennsylvanica*). Only 20 % of full sunlight was available at a height of 1.5 m.

We designed the plantation trial as a split-split-plot randomized block design with 4 replicates and three factors: overstory retention levels, planted species and vegetation control intensity. Four overstory retention levels were established in main plots of 1 ha: (1) 10 residual trees/ha, (2) 50 residual trees/ha, (3) 20-m strip cutting, and (4) control (400-600 stems/ha).

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Site preparation was necessary to initially eliminate understory vegetation in all planted plots. White pine (*Pinus strobus*) and white spruce (*Picea glauca*) seedlings were planted in 30 x 40 m subplots in June 2002. Vegetation control intensity was assigned to 30 x 20 m sub-subplots. This treatment was conducted during the third growing season (2004). Seedlings were partially or totally released from understory competition with brushsaws. Partial release was done on 1 m on each side of the seedlings in plots with 5 m spacing between planting rows, thus leaving a 3 m strip of natural regeneration and competing vegetation strip (Figure 1). Total release eliminated all competitive vegetation.

We measured seedling total height (Ht) and ground level diameter (GLD) at the time of planting and after four growing seasons on a total of 640 seedlings (4 blocks x 4 retention x 2 species x 2 veg. control x 10 sampled seedlings). Light availability at 1.5 m in height was calculated from hemispherical photographs taken in June 2002. Also, we measured photosynthetically active radiation (PAR) in July 2004 and 2005 using a sunfleck ceptometer, following the method described by Parent and Messier (1996). Half the measured seedlings were monitored for light availability, and results are expressed as percent of above-canopy readings. All data were submitted to analysis of variance to detect main effects and interactions, using the Mixed procedure of SAS (version 9.1).

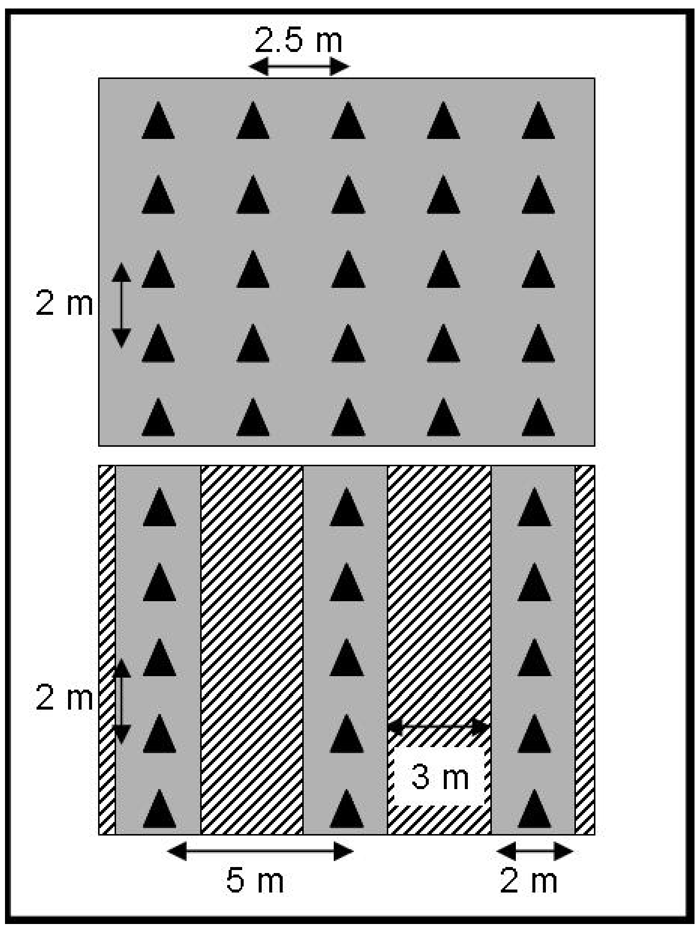

Figure 1. Experimental design of a subplot. In the total release treatment (top), seedlings have been planted with a 2 x 2,5 m spacing, and all competitive vegetation was removed in 2004. In

the partial release treatment (bottom), seedlings have been planted with a 2 x 5 m spacing. A 2 m-strip was released in 2004 leaving a 3 m-strip intact.

Results and discussion

Seedling survival after four growing seasons was 91 % and it was not influenced by the treatments. For the variables studied, treatment effects are additive (i.e. no interaction). Therefore, we present only main effects (Table 1).

Table 1. Retention level, planted species and vegetation control effects on percent of full light in 2002 (PAR_02), 2004 (PAR_04) and 2005 (PAR_05), and on seedling height (Ht_05), ground level diameter (GLD_05) and browsing occurrence (Brow_05) in 2005.

	PAR_02	PAR_04	PAR_05	Ht_05	GLD_05	Brow_05
	%	%	%	cm	mm	%
Retention						
10 trees/ha	**93 [a]**	41 [a]	**74 [a]**	115 [a]	**26.1 [a]**	9.4 [a]
50 trees/ha	**78 [c]**	30 [a]	**58 [b]**	106 [a]	**23.1 [ab]**	11.3 [a]
20-m strip	**84 [b]**	34 [a]	**59 [b]**	99 [a]	**22.0 [ab]**	15.6 [a]
Control	**62 [d]**	36 [a]	**48 [b]**	88 [a]	**18.7 [b]**	17.5 [a]
Species						
White spruce	79	37	64	103	21.5	**5.0**
White pine	80	34	55	101	23.5	**21.9**
Veg control						
Partial	79	33	**56**	**96**	**21.2**	**18.4**
Total	80	38	**63**	**108**	**23.8**	**8.4**

Bold indicates significant results at $p<0.05$ level. For a given retention treatment, means followed by the same letter are not significantly different, according to Fisher's protected LSD test.

Retention

After four growing seasons, planted seedlings of both species had similar total height. However, seedlings growing under 10 trees/ha had larger diameters than seedlings in the control plot. At the time of planting, in absence of competing vegetation, the proportion of full sunlight at 1.5 m showed significant differences among the four overstory treatments. However, two years later, before vegetation management (2004), light at seedling level (average height = 80 cm) was similar in all treatments. In 2005, seedlings in the 10 stems/ha plots received significantly more light than seedlings in the other plots. Thus, initial differences in light regime between the retention treatments were not maintained at the seedling level. This result shows the influence of the understory vegetation dynamics on the light regime and planted seedling performance.

Species

White pine and white spruce received the same amount of light during the study period. Both species performed similarly in terms of growth despite significant differences in browsing occurrence. In 2005, browsing pressure was over four times greater on white pine.

Vegetation control

The impact of vegetation control was immediately detected. While there was no difference in PAR before vegetation control, partially released seedlings received less light than those totally released. Also, fewer seedlings were browsed in the totally released plots compared to the partially released plots. Total height and diameter were significantly increased by complete release.

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Theme: Silviculture

Planning timber harvest of residual forest stands without compromising bird and small mammal communities in boreal landscapes

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According to current Quebec regulations, residual forest stands can be harvested when adjacent regeneration reaches 3 m in height. Little is known, however, on whether such regenerating habitat (RE-3m) can maintain wildlife communities similar to those found in undisturbed mature forest (CO). In order to compare wildlife densities and community structure between RE-3m and CO, we estimated the relative densities of 49 species of small mammals (n=2) and birds (n=47) in 10 RE-3m and CO sites. We then characterized the landscape configuration and stand structure for those sites. Six species were found at higher densities in RE-3m than CO, while 3 exhibited lower densities in RE-3m. No significant difference was observed for 12 other bird species. We built 26 statistical models that explained between 64.3 and 99.1% of the total variability in density. Following variance partitioning, stand structure variables accounted for most of the explained variability (54.2%) while landscape configuration variables accounted for 28.7%. Models also showed that bird community evenness was greater in CO than RE-3m, and that bird species were distributed along two gradients: 1) from regenerating stands to undisturbed "inland" forest and 2) from simple to complex stand structure. Our results suggest that wildlife community integrity, as well as some bird and mammal abundances, can be compromised if residual stands are harvested when adjacent regeneration reaches 3 m in height.

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Theme: Wildlife

Germination and seedling development patterns of six Acadian conifers in different microenvironments

Schatz, Jason[1]

Before reaching reproductive maturity, trees have to survive several limiting life stages. Each life stage acts as a filter, limiting the number of trees reaching successive stages. Susceptibility to competition and environmental stress is highest during early life stages, making them powerful determinants of forest composition. Critical early life stages include: 1) Seed germination, 2) Germinant establishment, and 3) Survival of established germinants over their first growing season. We compared germination and developmental dynamics during the first growing season (stages 1 & 3) of six common Acadian forest conifers: *Picea glauca*, *Picea mariana*, *Picea rubens*, *Pinus strobus*, *Abies balsamea*, and *Tsuga canadensis*. Germination and subsequent growth were compared under two light regimes, moderate shade (40% of full sun) typical of a partial overstory and deep shade (10% of full sun) typical of a full overstory. Germination dynamics varied widely among species in response to light and temperature. Seedling response to shade varied with species in terms of overall size, morphology, and growth allocation strategies. Overall, the three *Picea* species behaved similarly, while *P. strobus*, *A. balsamea*, and *T. canadensis* exhibited distinct germination and growth patterns.

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Theme: Tree physiology, carbon and nutrient cycles and genetics

Predicting rot and round-wood end use volume in trembling aspen (*Populus tremuloides* Michx.)

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In Quebec, predicting net merchantable volume of standing trees is essential to adjusting stumpage fees. Furthermore, round-wood end use is important in the provincial forest management context because it is used to split the allowable annual cut among the different mill types. A method relying on linear, binominal and multinomial regressions is proposed to predict both rot volume and round-wood end use volume. Tree age, height and quality, as well as ecological region, stand origin and presence of *Phellinus tremulae* and *Ceratocystis fimbriata* fungi are the main factors that contribute to quantifying the presence and the proportion of rotten merchantable volume. Once the net merchantable volume is estimated, the breakdown to round-wood end use is achieved through a series of steps involving the presence of *Phellinus tremulae*, saw log height, stem quality and size as explanatory variables. The first step is a multinomial regression that predicts the number of end uses that are present in the stem (pulp wood, low-grade saw logs, saw logs, low-grade veneer, and veneer). A series of logistical regressions then determines the presence of each end use, with linear regressions predicting the round-wood volume of each end use.

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Theme: Modeling, growth and yield

Expanding the spruce budworm decision support system to include aerial spray costs, wood products, and carbon

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The Spruce Budworm Decision Support System (SBW DSS) quantifies the marginal timber supply (m^3/ha) benefits of reducing spruce budworm (*Choristoneura fumiferana* Clem.) defoliation through insecticide application. While it is a useful tool for pest managers, its utility could be increased by incorporating values in addition to timber volume. Our objectives were to: 1) modify the existing SBW DSS to prioritize stands according to volume per dollar cost of protection, wood products value per dollar cost of protection, and sequestered carbon in trees kept alive per dollar cost of protection; and 2) apply the model to the 430,000 ha New Brunswick Crown Timber License #1. We describe the methodology used to: 1) quantify the relationship between aerial spray costs and spatial spray block variables; 2) construct scenarios that account for the spatial configuration of the spray block, the extent of the program, and defoliation classes; 3) construct carbon yield curves based on species, age, and silviculture treatment; 4) construct wood product yield curve-based pulpwood and sawlog product ratios for each stand type; and 5) integrate the above components into the SBW DSS framework. Implementation of the modified SBW DSS for the landbase is described and shown in maps depicting the prioritization of stands based on the new components.

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Theme: Forest management, operations and engineering

How many trees did you plant today? An exploratory study of the factors affecting the productivity of a group of planters working in the Abitibi and Outaouais regions of Quebec

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Because a tree planter's salary depends on the number of trees that he or she plants each day, it is important to identify the factors that may influence a planter's productivity. With this objective in mind, 11 variables were monitored over a 3-month period with respect to their effect on the productivity of 12 tree planters working in the Abitibi and Outaouais regions of Quebec. Six factors significantly affected the number of seedlings planted/hour: individual planter, number of days since the beginning of the study, time required to reach the planting site (vehicle and walking), number of hours worked per day and monetary compensation per plant. These factors are all related to the planter's level of experience, fatigue and motivation. Although site characteristics (debris, competition, planting density) and seedling type did not have a significant effect on overall productivity, they did influence the performance of individual planters. The results of this study are limited by the number of planters and sites studied. A more accurate portrait of planter productivity would be obtained by expanding the study to include more planters, other regions of the province, environmental conditions and a longer time frame.

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Theme: Forest management, operations and engineering

Genetic variability in the root architecture of 2+0 white spruce seedlings

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To reduce the quantity of seedlings that fail to meet morphophysiological criteria at delivery and quantify the genetic variability of root system morphology, containerized white spruce seedlings from 75 open-pollinated families were evaluated after two growing seasons under nursery conditions. During their first year of growth, the seedlings had been subjected to two different fertilization regimes: optimal and sub-optimal. The following traits were investigated: colonization of the root plug, length and orientation of the primary root as well as the number, growing angle, distribution and reorientation of lateral roots. Family had a significant effect on only one of the variables studied: growing angle of first order lateral roots in the upper 25% of the container cavity. A profile analysis showed that the majority of the families had lateral roots growing out of the primary root at an angle of <30º, whereas six families had an elevated number of roots growing at angles of between 30º and 50º. Detailed analysis and observations showed that the greater growing angle was only evident in seedlings that had been subjected to the sub-optimal fertilization regime during their first growing season. This characteristic may be an attempt to exploit the nutrient reserves in a larger volume of the root plug. Our results confirm the sensitivity of white spruce root systems to differences in substrate fertility and indicate that not all families exhibit the same type of adaptation to nutrient stress.

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Theme: Tree physiology, carbon and nutrient cycles and genetics

Dead wood dynamics and the legacy of spruce budworm outbreaks

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Spruce budworm (*Choristoneura fumiferana* Clem.) outbreaks cycle every 35 years, typically last 5-15 years, and cause extensive mortality for up to 10 years in balsam fir (*Abies balsamea* (L.) Mill.) − spruce (*Picea* spp.) stands, resulting in pulses of dead wood that lag slightly behind the actual timing of the outbreak. This study documents dead wood levels and rates of blowdown following the 1971-1993 spruce budworm outbreak in 585 balsam fir/spruce plots with different levels of defoliation and mortality. A sub-sample of 50 plots were surveyed for dead wood in 2003-2005, from which a 15-18 year time since death sequence was constructed for 1160 dead inventoried trees and 859 corresponding pieces of downed dead wood. The dominant cause of death shifted from spruce budworm in 1987-1993 to wind-related causes thereafter. Insect-killed trees produced intact snags, while wind-related causes resulted in mechanical breakage of the stem (uprooted, stem breakage, broken top), affecting rates of snag fall and incremental height reduction over time.

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Theme: Forest ecosystems

Scarification and fertilization: Facelift creams for *Kalmia* heath?

Thiffault, Nelson[1]

Conversion of productive forests into ericaceous heath following wildfires or cutting poses a threat to the maintenance of forest productivity. These sites are frequently characterized by a dense *Kalmia angustifolia–Rhododendron groenlandicum* cover, which induces forest succession stagnation. I report on the 15th-year results of a technical trial established in northeastern Québec, where silvicultural options to successfully re-establish conifers on such sites are being studied. The trial was established to evaluate the performance of various conifer species when planted with or without mechanical scarification, and to measure growth and survival impacts of fertilizer amendment at time of planting. In the absence of mechanical scarification, local screefing with a modified brushsaw was viewed as a potential alternative and tested. Fifteenth-year height of *Picea mariana*, *Pinus banksiana* and *Larix sibirica* significantly responded to the combined effects of screefing and fertilization ($p \leq 0.036$). Responses to the various treatment combinations were species specific, but the screefed and fertilized plots always included the tallest trees. Although the layout of the trial did not allow formal comparisons between the unscarified and mechanically scarified sectors, mechanical site preparation was clearly needed to rejuvenate the planted areas and bring back significant forest productivity.

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Theme: Silviculture

Clonal forestry

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Somatic embryogenesis is presently the most powerful technology for plant propagation of coniferous species. Coupled with cryopreservation, it allows clonal testing and selection of superior genotypes to be later used in reforestation programs. In 1996, seeds from six full-sib families of white spruce (*Picea glauca*) were used to produce clonal plants through somatic embryogenesis. A total of 1080 trees were produced representing 48 clones. Clonal trees and zygotic seedlings from each family were grown for one season in the greenhouse and overwintered under snow before being planted in the field in May 1998 as a randomized complete block design. Height and diameter were measured in 1997, 1998, 1999, 2004 and 2005 and statistically analyzed. Variations observed among and within clones will be presented and compared with control plants of the same families.

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Theme: Tree physiology, carbon and nutrient cycles and genetics

Effects of forest clearcutting on salamander migration and dispersal

Veysey, Jessica S.[1] and Kimberly Babbitt[2]

Conservation of vernal-pool-breeding amphibians is inhibited by inadequate understanding of the amphibians' upland habitat requirements. For one such species, spotted salamander (*Ambystoma maculatum*), survival may depend on metapopulation maintenance, but little is known about its inter-patch dispersal mechanisms. Upland buffer zones around vernal pools have been proposed as a management strategy for these amphibians. However, substantial validation of such buffer zones, in the form of experimental upland habitat disturbances, has yet to occur. Specifically, no studies have examined the immediate effects of clearcutting on spotted salamander migration and dispersal. In this study, we used clearcutting to experimentally manipulate upland buffer widths at eleven vernal pools. We then conducted intensive radio tracking, and marked recapture at pitfall traps, to observe effects of clearcutting on spotted salamander movement. A total of 40 salamanders (25 females, 15 males) were tracked for an average of 124 days (range: 6 to 270 days). Mean maximum migration distance for females was 120 m (range: 1.6 to 405 m), and for males was 83 m (range: 3.9 to 288 m). At the clearcut treatment pools, 20% of females and 29% of males successfully crossed the clearcut. Results from this study will be used to improve forestry best management practices.

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Theme: Wildlife

The cooperative forestry research unit: 30 years of partnership between Maine's forest managers and the University of Maine

Wagner, Robert G.[1] and Spencer R. Meyer[2]

In 1975, a small group of visionary forest industry leaders from Maine and representatives of the University of Maine formed the Cooperative Forestry Research Unit (CFRU). It is now one of the oldest industry / university forest research cooperatives in the United States, and continues to serve as a model of joint leadership and cooperation between Maine's largest industry and the University of Maine. The CFRU is composed of about 25 private and public forestland management organizations from across the state that guide and support research on key forest management issues facing Maine's forest landowners and managers (www.umaine.edu/cfru). The mission of the CFRU is to *"conduct applied scientific research that contributes to the sustainable management of Maine's forests for desired products, services, and conditions."* The CFRU has been generously supported for 30 years through the voluntary financial and in-kind contributions of its members. CFRU research continues with a focus on improving silviculture in the Maine forest and improving our understanding about the influence of forest management on wildlife habitat and conservation of biodiversity. The CFRU has had a positive and lasting influence on the forestry culture at the University of Maine by providing a direct link between the university and the people managing Maine's forestland.

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Theme: Silviculture

The influence of local-scale stand structure on growth and development of mixed red oak – white pine stands in Maine

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For structurally complex, mixed-species stands, a biologically meaningful scale of record-keeping and management may exist between the full stand and the individual tree. Forests classified as the mixed red oak – white pine habitat type cover almost 1.5 million acres in the state of Maine, most of it on small ownerships subject to low-intensity management. The Massabesic Experimental Forest (MEF) in York County, Maine is the only USDA Forest Service experimental forest in the country with appreciable amounts of this important type. We are conducting a study of local-scale structure at the MEF, and its effects on growth and development. Our objectives are to (1) determine the range and spatial distribution of local-scale structural variation within MEF stands; (2) evaluate the effect of local-scale structure on growth and yield; (3) examine the effect of local-scale structure on the development of advance regeneration; and (4) identify factors that drive the development of different local-scale structural characteristics. We anticipate that the results of this study will improve understanding of dynamics in mixed-species stands, and facilitate management of oak – pine forests on small ownerships.

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Theme: Modeling, growth and yield

Tolerant conifer regeneration on decaying wood: A perspective from the Acadian forest

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Past research on downed woody material has established its importance in nutrient cycling, wildlife population dynamics, inputs into stream systems, and as a germination substrate for vascular plants. However, there is little information about the role of downed wood in the Acadian Forest of northeastern U.S. and eastern Canada. This forest represents an overlap of tree species' ranges from temperate and sub-boreal climates, creating a diverse species mixture. We are interested in the differential use of downed wood as a regeneration substrate by common tree species. This study, conducted in Maine on the Penobscot and Massabesic Experimental Forests and the Holt Research Forest, focuses on two signature tolerant conifers of the Acadian Forest: red spruce (*Picea rubens* Sarg.) and eastern hemlock (*Tsuga canadensis* (L.) Carr.). The abundance and proportion of regeneration on downed wood versus the forest floor will be presented, as well as the effects of forest management and forest type on those relationships. We anticipate that our findings will provide insight into the ecology of tree seedling germination and growth in the Acadian Forest, and thus facilitate successful silvicultural treatment.

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Theme: Forest ecosystems

Identifying selected internal log features from computed tomography images

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Abstract

The properties and value of lumber are influenced by internal log features such as defects (e.g. knots, decay). Knowledge of internal log features is useful to the optimization of log breakdown for maximum value. In recent years, computed tomography (CT) has been used to acquire internal log features nondestructively. The main objective of this study is to develop automatic methods for CT image segmentation and labeling of selected log features. This preliminary study investigated two internal log features in beech, i.e., sapwood and heartwood. Class separability was assessed. Maximum likelihood classifier was employed for the image segmentation of these features. The results show that the combination of gray level value with textural information produces accurate segmentation of the sapwood and heartwood in the log.

Keywords: Beech, Computed Tomography (CT) image, internal wood features, separability, recognition

Introduction

For the lumber industry, the value of lumber from a log is dependent mainly upon the primary log breakdown. Different sawing methods may greatly affect the lumber value. For decades, the primary log breakdown has been based on external log geometry. While this sawing strategy is intended to maximize the lumber volume recovery, it does not necessarily lead to maximum product value because the sawyer uses only external characteristics and his experience to cut the log without prior information on the internal wood characteristics which determine the grade of each sawn board. Studies show that for hardwoods, potential gains of about 10% in lumber value could be achieved if the internal log information is considered (Richards 1977).

In recent years, computed tomography (CT) (Hounsfield 1980, McMillin 1982) has been employed to characterize internal log characteristics nondestructively. CT images have been used to characterize many important wood properties (Oja and Temnerud 1999). The knowledge of internal log characteristics, which are derived from CT images, can be used not only for the above mentioned optimization of log breakdown but also for other applications, such as lumber

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drying and quality control. Some approaches have been used to detect internal log features using CT images. However, few studies have investigated the usefulness of spectral and textural image variables in separating different internal features of logs. This research will focus on the class separability analysis and establishment of a maximum likelihood classifier based on using the spectral and textural variables which give the best separability between sapwood and heartwood.

Materials and methods

Materials A beech (*Fagus grandifolia* Ehrh.) log was used for this study. It was scanned by Siemens's SOMATOM Plus 4 Volume Zoom CT system. Twenty CT images of the cross sections of the log were randomly selected for the class separability analysis and the establishment of the classifier. Each image was 512×512 size with a radiometric resolution 8 bits and pixel resolution was around 0.7mm/pixel. Sapwood and heartwood in the log were selected as internal features for recognition.

Variables selection Several spectral and textural variables were tested. The spectral variable corresponds to the raw Gray Level value (GL). GL value represents the brightness of each pixel in the CT image. For this study, mean GL value of the raw images was used to extract GL information. Textural information represents the spatial distribution of pixels GL values in an image region. Six textural variables were used to extract the textural information, including *Contrast*, *Homogeneity*, *Dissimilarity*, *Mean*, *Standard Deviation* and *Energy* (Haralick et al 1973). The formula for computing each variable is given in Table 1.

Table1. The formulas for the different variables (Haralick et al 1973)

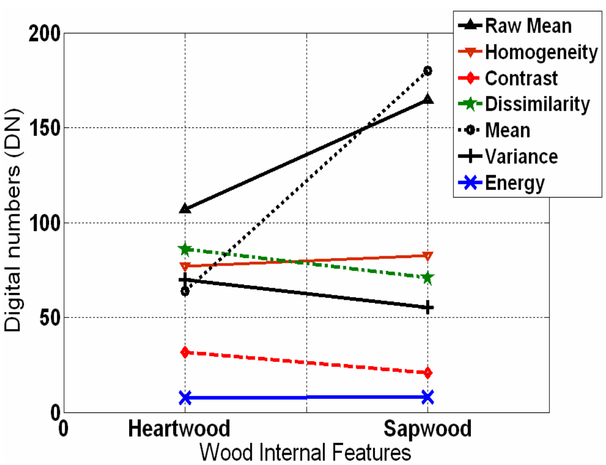
Variable		Formula	Description
Spectral variable	Mean GL value	$\frac{1}{L}\sum_{i=1}^{L} GL(i)$	*GL(i)* is the GL value of the ith pixel; L is the number of pixel.
Textural variables	Homogeneity	$\sum_{i=0}^{N-1}\sum_{j=0}^{N-1}\frac{p_{ij}}{\left[1+(i-j)^2\right]}$	P_{ij} is unnormalized counts of how many times two neighboring pixels which are separated by a displacement, e.g., one pixel, occur on the image; one with GL value *i* and the other with GL value *j*. *N* is the dimension of GLCM matrix which is used to compute the textural information.
	Contrast	$\sum_{i=0}^{N-1}\sum_{j=0}^{N-1}(i-j)^2\times p_{ij}$	
	Dissimilarity	$\sum_{i=0}^{N-1}\sum_{j=0}^{N-1}\left(\lvert i-j\rvert\times p_{ij}\right)$	
	Mean	$\sum_{i=0}^{N-1}\sum_{j=0}^{N-1} i\times p_{ij}$	
	Standard Deviation	$\sqrt{\sum_{i=0}^{N-1}\sum_{j=0}^{N-1}(p_{ij}\times(i-\sum_{i=0}^{N-1}\sum_{j=0}^{N-1} i\times p_{ij})^2)}$	
	Energy	$\sum_{i=0}^{N-1}\sum_{j=0}^{N-1} p_{ij}{}^2$	

The usefulness of variables in separating sapwood and heartwood needs to be assessed first to make sure that the variables to be used will separate sapwood from heartwood quite well. Two methods were used to test class separability. The first method computes mean values of GL values and of the six textural variables which were scaled into the same range of GL (or DN, i.e., Digital Numbers), i.e., 0 to 255 for convenient comparison. These mean values are then compared graphically. The second method uses *Jeffries-Matusita* (J-M) distances as defined by Richards (1994).

The classifier Maximum likelihood classifier was employed for the classification. Based on probability Bayes theory, it is the most popular classifier in remote sensing. To date few studies have used this classifier for the recognition of internal logs features.

Results and discussion

Results of separability assessment The results from the first and second methods are shown in Figures 1 and 2, respectively.



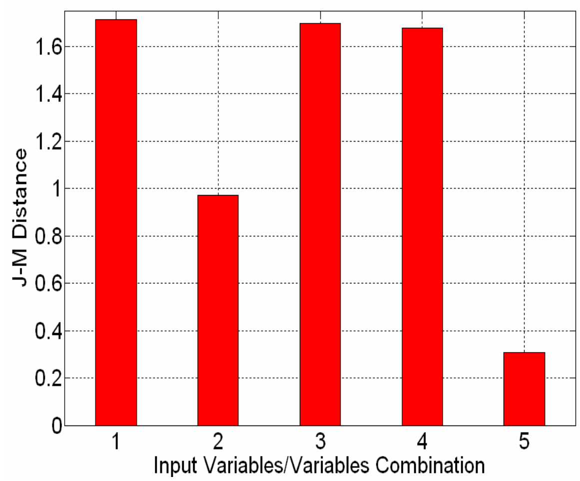


Figure 1. Separability analysis using DN value

Figure2 Separability analysis using J-M distance.

The graphical comparison (Figure 1) between mean values of the spectral and textural variables shows that the difference between mean value of sapwood and of heartwood is the greatest for *Mean* (116.172) and the smallest for *Energy* (the difference is 0.463).

Using J-M distance applied to five combinations of images: 1: all seven variables combination; 2: only mean GL values of the raw image; 3: all seven variables but mean GL values of the raw image; 4: all seven variables but mean GL values of the raw image and *Standard Deviation*; 5: all seven variables but mean GL values of the raw image, *Mean* and *Standard Deviation*. Based on Figure 2, all seven variables combination has the greatest J-M distance (1.712) which means this type of image combination leads to the best separability between heartwood and sapwood. Low J-M distances correspond to image combinations without the *Mean* image (type 2 and type 5, i.e., 0.970 and 0.309 respectively); it suggests that *Mean* has a very important effect on class separability.

Results of identification One raw CT image of the beech log cross section and the corresponding classified image using the maximum likelihood classifier are shown in Figure3 respectively.

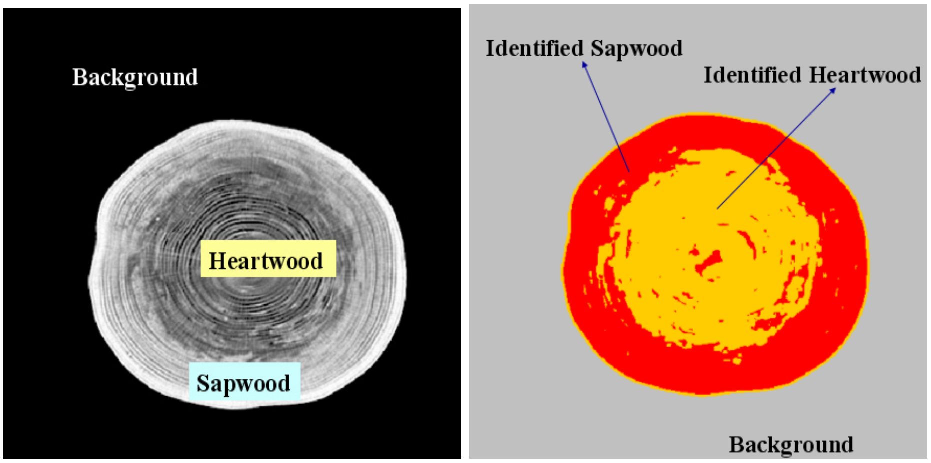


Figure3. (a) Raw image (b) Classified image

Accuracy analysis For the evaluation of the classifier accuracy, a standard confusion matrix was constructed (Table 2). The ideal situation is the diagonal matrix, because it indicates that the 100% pixels recognized as class *i* really do belong to class *i*.

Table 2. Confusion matrix

	Manually Classified Image			
Classified Image	Background	Sapwood	Heartwood	Totals
Background	0	0	0	0
Sapwood	0	38	7	45
Heartwood	1	4	50	55
Totals	1	42	57	100

The confusion matrix produces an Overall accuracy of 88.0%; and an overall *Kappa* coefficient of 0.759 which means that the classification is fairly accurate. Based on the confusion matrix, heartwood was not well separated compared with sapwood.

Conclusions

Based on this preliminary study, the following conclusions can be drawn: 1) Using the combination of the seven variables has the best capability of separating sapwood and heartwood in beech log; 2) *Mean* has a very important effect on the classification accuracy; 3) Maximum likelihood classifier produced an accurate recognition of sapwood and heartwood using the combination of the seven variables. Future work will focus on identifying knots.

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Acquiring and testing multiband orthophotography (and integrated LiDAR) for production of enhanced forest inventories in the Great Lakes–St. Lawrence forest

Woods, Murray[1], John Pineau[2] and Paul Courville[2]

A 3-year project (2005-2008) is investigating the potential of multiband (red, green, blue and near-infrared) orthophotography and integrated airborne LiDAR for the production of enhanced forest inventories in the Great Lakes–St. Lawrence forest region. Specifically, the study focuses on forest cover types as well as stand level attributes and is attempting to develop automated or semi-automated methods of enhanced inventory estimation for individual tree classification using both digital imagery and LiDAR data. As well, the project is exploring applications of wetland mapping and stream identification using the same technology. Ultimately, the study will provide an improved description of forested and unforested conditions in the Great Lakes–St. Lawrence forest region landscape. Recent efforts by Tembec Inc. have demonstrated a much finer description of Boreal forest region conditions through the semi-automated interpretation of a combination of similar digital imagery and LiDAR data than is possible through traditional means. The project also includes an aggressive and proactive extension component so that new inventory applications that result, and are suitable for forest management planning and operations, can be put into practice without delay. Long-term spin-off benefits of the project potentially include significantly improved forest management planning, modeling, operations, silviculture, road building, forest values identification, wetland evaluation, ecological land classification, carbon cycling; and potentially major corresponding cost decreases for both the forest industry and the Ontario Ministry of Natural Resources.

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Theme: Forest management, operations and engineering

Development and validation of a watershed forest management information system

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In order to protect water quality and quantity, a decision support system, Watershed Forest Management Information System (WFMIS), has been developed with Visual Basic® and ArcObjects® in ArcGIS®. There are three subsystems: Watershed Management Priority Indices (WMPI) is a zoning method for forest management planning with respect to soils, water, and aquatic ecosystems; Forest Road Evaluation System (FRES) is a module to evaluate roads and road-stream crossings in order to develop and implement effective preventive maintenance, and Harvest Scheduling Review System (HSRS) is a module to estimate the cumulative hydrologic effect of timber harvesting on water yield and associated changes in water quality. The system is an extension to ArcGIS® 8 and above. It needs commonly available GIS data and has user friendly interfaces to assist foresters and planners to manage the watershed in an environmentally healthy way.

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