Boreal Mixedwoods 2012

Ecology and Management for Multiple Values

June 17-20, 2012

Delta Edmonton South, Edmonton, Alberta
Western Boreal Growth and Yield Association

Government of Alberta Sustainable Resource Development

CIF Forest Ecology Working Group
It is a pleasure to welcome you to the Boreal Mixedwoods 2012 conference.

This conference is intended to provide a forum for discussion of current knowledge relating to the ecology and management of mixedwood stands and landscapes to achieve ecological, social and economic objectives. Participants bring with them a broad range of interests and experiences, which we hope will be shared.

The conference is hosted by the Canadian Wood Fibre Centre, the University of Alberta, the Western Boreal Growth and Yield Association, the Canadian Institute of Forestry – Forest Ecology Working Group, and IUFRO working group 1.01.00 – Temperate and boreal silviculture.

Financial support for the conference is being provided by:
- Canadian Wood Fibre Center
- Alberta Sustainable Resource Development
- Western Boreal Growth and Yield Association
- Canadian Institute of Forestry – Forest Ecology Working Group
- University of Alberta – Faculty of Agricultural, Life and Environmental Sciences
- Alberta Mixedwood Management Association
- Canadian Institute of Forestry – Rocky Mountain Section

Members of the planning committee for the conference are: Phil Comeau, Dan MacIsaac, Rongzhou Man, Art Groot, Gitte Grover, Brian Harvey, Derek Sidders, Ken Greenway, and Richard Kabzems. Our planning team has invested substantial time and energy in the development of what we hope you will find to be an interesting and informative conference.

Boreal Mixedwoods 2012 – Ecology and Management for Multiple Values
June 17-20, 2012
Delta Edmonton South, Edmonton, Alberta

Conference Proceedings:

The advisory and planning board of the Boreal Mixedwoods 2012 conference has made arrangements with the Forestry Chronicle to publish approximately 10 selected papers in a special issue. You are invited to submit your abstracts to Rongzhou Man (rongzhou.man@ontario.ca) by June 30 through email. You can use the abstracts for your conference presentation or have different submissions as long as the contents are original, either in review or research paper format. The authors of those abstracts selected for publication will be notified by mid-July and full manuscripts will be due October 31, 2012. As required by the journal, the manuscripts should be original material including review as well as original articles (to be published as scientific/technical papers) and must follow the recommended formats (instructions for authors, http://www.cif-ifc.org/site/author_instructions). Please submit papers in MS-Word 2003 (*.doc) or MS-Word 2010 (*.docx) format. Papers will go through a peer review process. Please limit the paper length to around 10 journal pages, including figures and tables. The selected manuscripts after peer review and revision are expected to be published prior to mid 2013. There will be no page charge, whether black and white or color graphics.

We appreciate the assistance of John Pineau in arranging for sponsorships to defray publication costs.

As part of the issue, we are also looking for cover photos in high resolution (300 dpi at 8” x 8” in portrait format). The photos also need to be original and have not been used by the Forestry Chronicle or other journals. Please do not hesitate to show your work if you have good images pertaining to boreal mixedwood ecology and management.

Conference Website

The conference website will be maintained. We will post powerpoint presentations and/or presentation summaries, and posters (in pdf format) with permission from each speaker.
Boreal Mixedwoods 2012 Conference Program (June 6 2012; subject to change)

Sunday June 17, 2012 1900-2100 - Registration and Opening Reception (Crystal Gallery)

Monday June 18

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| 0830-1010 | **Panel on Policy Issues** (Ken Greenway chair)  
Panel Members: Qc Nicolas Lecomte, ON  Rongzhou Man, MB Andy Grauman, SK Vicki Gauthier, AB Ken Greenway, BC Allan Powelson |
| 1010-1030 | Break                                                                    |
| 1030-1110 | **Glen Armstrong – Economic Considerations for Mixedwood Management**   |
| 1110-1150 | **Dan MacIsaac - Challenges in Mixedwood Management: What have we learned over the past 25 years** |
| 1150-1250 | Lunch ([Royal Room](#))                                                   |
| 1250-1410 | **Panel Discussion - Opportunities and Challenges** (Phil Comeau Chair). Panel Members: Vic Lieffers, George Bruemmer, Yves Bergeron, Gordon Whitmore, Paul LeBlanc |
| 1410-1450 | **Phil Comeau - Mixedwood management for the late 21st century – what might the future hold?** |
| 1450-1510 | Closing Remarks – Dan MacIsaac and Phil Comeau                          |
ABSTRACTS

Keynote Talks

SPECIES AND STAND DYNAMICS IN THE MIXED-WOODS OF QUEBEC'S BOREAL FOREST: A GUIDE FOR ECOSYSTEM MANAGEMENT

Yves Bergeron
Université du Québec en Abitibi-Témiscamingue.
yves.bergeron@uqat.ca

Species and stand dynamics were reconstructed for mesic sites in the mixed-boreal forests surrounding Lake Duparquet in northwestern Quebec and originated from 8 successive fires representing a chronosequence of 230 years. Composition shows a gradual change with time since fire from stands dominated by deciduous (aspen and paper birch), to mixed stands with an important white spruce component, to coniferous stands dominated by balsam fir and white cedar (Figure 1). Despite variations in the age and composition of the stands before the last fire, they generally follow a common pattern characterized by post-fire hardwood dominance. Age structures show successive waves of aspen, birch and fir recruitment, corresponding respectively to the post fire cohort, the gradual dismissal of the first aspen cohort and to spruce budworm outbreaks. Each of these waves corresponds to a decrease in hardwoods and an increase in the conifer component of the stand. Suppressed white spruce individuals, recruited primarily as part of the post-fire cohort, experienced growth releases following the dismissal of the first aspen cohorts. White cedar increased in abundance late in succession and tended to outcompete balsam fir in old coniferous stands severely affected by spruce budworm outbreaks. The observed multi-cohort process contrasts with the simple replacement of hardwoods by conifers as suggested by observations of differential growth rates. This gradual rate of change, occurring over several generations, results in the maintenance of an important hardwood component in most stands even in the absence of fire. After 230 years, stands are still mainly composed of trees originating from punctual events such as fire, the gradual dismissal of the first aspen cohort or spruce budworm outbreaks. The study confirms that changes in forest composition observed while sampling portions of the landscape originating from different fires may be explained by simple processes occurring at the stand level. Results were used in the development of an ecosystem management approach for the Lake Duparquet Research and Teaching Forest. A silvicultural system inspired by natural dynamics, in which fire is emulated by clear-cutting and natural canopy succession is imitated by partial cutting, was developed (Harvey et al, 2002). Even-aged stands dominated by deciduous species but with an understory of conifers are partially cut in order to reproduce succession towards mixed stands composed of deciduous and conifers. These stands can be partially cut again to produce pure conifer stands. Insect outbreaks and gap dynamics that occur in late successional conifer stands could also be emulated using partial and selection cutting. At the landscape level, the proportions of stands belonging to deciduous mixed and conifer compositions are determined in order to represent the proportion that would be observed under a natural disturbance regime. The emphasis on maintaining forest type diversity contrasts significantly with current even-aged management techniques in the Canadian boreal forest, and has important implications for stand-level interventions, notably in necessitating a greater diversification of silvicultural practices including more uneven-aged harvesting methods.
Figure 1. Natural forest succession in the Lake Duparquet mixedwood boreal forest. The top panel illustrates succession from a broadleaf deciduous, to a mixedwood and finally coniferous stand along with the dominant disturbance agents, while the bottom panel illustrates the changes in tree species with time since fire (Bergeron, 2000). Upper panel also illustrates silvicultural treatments emulating natural disturbances as suggested in Harvey et al (2002).

REFERENCES
Diversity-productivity relationships in forest ecosystems: a dynamic perspective

Han Y. H. Chen¹, Brian W. Brassard, Peter B. Reich, Zhiyou Yuan, Yves Bergeron, David Paré⁵, Jérôme Laganière and Xavier Cavard
Faculty of Natural Resources Management, Lakehead University
hchen1@lakeheadu.ca

Although there is support for positive species richness–productivity relationships in planted grassland experiments, a recent 48-site study found no diversity–productivity relationship in herbaceous communities. Thus, debate persists about diversity effects in natural vs. planted systems. Additionally, current knowledge is weak regarding the influence of evenness on the diversity–productivity relationships (DPRs), how DPRs are affected by the variation in life-history traits among constituent species in polycultures, and how DPRs differ among biomes. The impacts of these factors on DPRs in forest ecosystems are even more poorly understood. We performed a meta-analysis of 54 studies to reconcile aboveground DPRs in global forest ecosystems and conducted an empirical of fine root productivity in boreal forest.

In the meta-analysis, we quantified the net diversity effect as log effect size [ln(ES)], the log ratio of the productivity in polycultures to the average of those in monocultures within the same type of mixture, site condition and stand age of each study. Global average ln(ES) was 0.2128, indicating 23.7% higher productivity in polycultures than monocultures. The final model explained 21% of the variation in ln(ES). The predictors that substantially accounted for the explained variation included evenness (34%), heterogeneity of shade tolerance (29%), richness (13%), and stand age (15%). In contrast, heterogeneity of nitrogen-fixation and growth habits, biome, and stand origin (naturally established vs. planted) contributed negligibly (each ≤4%). Log effect size strongly increased with evenness from 0.6 to 1 and with richness from 2 to 6. Furthermore, it was higher with heterogeneity of shade tolerance, and generally increased with stand age. Our analysis is, to our knowledge, the first to demonstrate the critical role of species evenness, richness, and the importance of contrasting traits in defining net diversity effects in forest polycultures.

The effects of tree species diversity on the productivity and niche utilization of fine roots of single- and mixed-species stands were studied in boreal forest that have grown naturally for 85 years on similar sites. Annual fine root production was 19% to 83% higher in mixed- than single-species stands. Fine root biomass was higher in mixed- than single-species stands in summer months, but not in spring or fall. Higher fine root productivity in mixtures than in monocultures was realized by filling more soil volume horizontally and vertically by growing into the deeper mineral soil in mixtures of deep-rooted species, or into the forest floor in mixtures of deep- and shallow-rooted species.

These results collectively demonstrate positive diversity effects on productivity due to trait and/or phylogenetic differences among the component species. They also provide evidence that the diversity effects in heterogeneous natural environments is realized by increased niche utilization over time from the different resource foraging behaviours of the component species and variations within species. Future work should examine whether tree diversity effects on ecosystem functions are stronger when ecosystem is under stress and how tree diversity may affect belowground diversity.
In Ontario, boreal mixedwood forest is long managed for conifers, mostly spruce. However, mechanical and chemical tending does not result in general occurrence of conifer dominance expected at regeneration stage, which caused a widespread concern in early 90s. With the increase of hardwood utilization, mostly aspen, through the 80s and 90s, the importance of managing mixedwoods for multiple species started to be realized, particularly with the advance of ecological theories in biodiversity conservation, ecosystem management, and disturbance-based silviculture. Boreal mixedwood forests at different scales (stand and site) were defined and silvicultural systems for species mixtures of desired conditions were developed. Partial harvesting with understory protection and increasing conifer components through underplanting were tested. Due to lack of desired conifers in mixedwood understory, strip planting and tending was practiced, instead, by companies. More recent research involves the use of herbicide prior to harvest to reduce aspen sucker density and size, without compromising sucker quality, and grow intimate tree mixtures of healthy aspen and conifers (spruce and jack pine) after clearcut. This is attractive to forest managers from less planting density for conifers and herbicide use (therefore lower cost) as well as reduced exposure of understory wildlife to herbicide, compared to common conifer plantations of clearcut, planting, and chemical tending.
Natural (and inexpensive) means of regenerating boreal mixedwood forests.

Victor J. Lieffers, S. Ellen Macdonald, Brigitte Grover, Kevin Solarik, Jonathan Martin-DeMoor and Stefanie Gärtner.
Dept. of Renewable Resources, Univ. of Alberta, Edmonton, AB
Vic.Lieffers@ales.ualberta.ca

The combination of aspen and white spruce in boreal mixedwood forests, while having many ecological benefits, has long been a headache for silviculturists, forest managers and regulators of forest activities on public lands. The spruce has much slower juvenile-growth rates and usually remains under the aspen for decades after a disturbance. There have been large amounts of resources spent on artificially establishing fully-stocked and pure stands of spruce but financial analysis suggests that these operations are not likely to be profitable. This presentation will explore alternative means of retaining spruce in boreal mixedwoods using natural regeneration systems. Seed sources (masting and tree distribution), seed beds, drought and competition from other vegetation will be considered. The influence of aspen on regeneration, including leaf litter, and competition for light will also be explored. Finally, the stochastic nature of natural regeneration produces a range of outcomes at the forest level. This means that forest managers and reforest regulations must be able to deal with a range of regeneration outcomes that occur with natural regeneration. Spruce outcomes may range from various levels of partial stocking to fully-stocked. Aspen regeneration often complements the stocking of spruce. Provided that most of the mixedwood landbase is available for promotion of natural regeneration of spruce, natural regeneration can be a viable means of retaining the spruce in these forests.
Advanced tools for forest inventory

Doug Pitt and Murray Wood
Canadian Wood Fibre Centre and Ontario Ministry of Natural Resources
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There is a growing need for up-to-date, effective, and efficient inventory systems that will allow our forest sector to realize maximum benefit and value from Canada’s forest resources. The business of managing the Nation’s forests - the sustainable management of our richest natural endowment - depends on better inventory, as does our forest industry and the hundreds of resource-based communities across this country. The Canadian Wood Fibre Centre is working with experts and practitioners from within the CFS, FPInnovations, the provinces, forest industry, our universities, and key geomatics consultants to research means of producing forest inventory data with more detail and accuracy than ever before possible. Collaborative work with the Ontario Ministry of Natural resources and Tembec will be highlighted in this presentation as an example of some of the recent achievements being made with airborne LiDAR (Light Detection and Ranging) to better predict fibre supply attributes, build more efficient and environmentally sound road systems, and identify key habitat features and sensitive areas. Implications for mixedwood management will be discussed, along with avenues of current research.
Economics of Forest Management in the Boreal Mixedwood

Glen W. Armstrong
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Since the end of the last century, there have been some notable changes in the economic climate of the boreal mixedwood forest in Canada: low product prices, a strong Canadian dollar, and increasing recognition of the importance of non-timber forest values have are major challenges that must be faced by forest managers and the landowners. In response to these challenges, we may need to rethink the objectives of forest management as stated in policy, and to rethink the silviculture prescriptions we apply to the forest. This rethinking may well lead to a forest with less annual production (at least in terms of softwood volume), but with greater economic value.
Challenges in Mixedwood Management:
What Have We Learned Over the Past 25 Years.

Dan MacIsaac
Natural Resources Canada, Edmonton
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In 1989, E.B and N.M. Peterson and A. and R.D. Kabzems produced a report for The Canadian Forest Service (then Forestry Canada) titled “Boreal mixedwood forest management challenges: a synopsis of opinions from 1988 interviews.” The timing of these interviews is important as it coincided with a period when hardwoods were gaining economic importance across The Prairie Provinces. Companies did not have much experience in mixedwood management at that time.

The primary objective of this report was to identify stand-level boreal mixedwood problems based on interviews of federal, provincial and industrial forestry staff. Interviews covered the area of boreal mixedwoods from eastern Manitoba to northeastern B.C. The most commonly mentioned concerns were: competition from shrubs and grasses after clearcutting; restriction to the silvicultural use of herbicides; difficulties to achieve coniferous spruce regeneration; uncertainties about the ecological effects of site preparation; ill-defined management regimes for mixedwood ecosystems; difficulties in managing and using decayed aspen; inadequate inventory data on boreal hardwoods and understory conifers; and inaccurate allowable annual cut projections now that hardwood species are commercially important. The main message revealed by this review was that the co-existence of aspen and spruce on the same site represents a well adapted mix of species, but such ecosystems present perplexing silvicultural problems.

There have been a number of trends in the past 25 years which have influenced these mixedwood challenges. This includes a wide body of research which has greatly increased our understanding of the autecology and silvics of the major boreal tree species; development of tools and technologies which have utilized this research (e.g., the boreal mixedwood silviculture guide produced by Mixedwood Management Association of Alberta); a much enhanced inventory because of development of tools such as Lidar; development of the new frameworks of understanding boreal mixedwoods (such as disturbance-based ecosystem management); changed utilization standards that influence stand structure (e.g., balsam poplar is now routinely harvested whereas 25 years ago it was mostly left in the block); increase in partial harvest systems, as well as a move to grow aspen and spruce as “intimate mixtures”, in keeping with their natural ecological distribution. There have also been the occurrence of new challenges to mixedwood management. Foremost is the phenomena of climate change, which poses increased risk to the regeneration and growth in boreal mixedwoods due to moisture stress, increased fire and insect outbreaks. A recent economic challenge has been the downturn in the forest industry. This has reduced the resources that can be applied to silvicultural and management activities, requiring us to be more judicious in their application.

I will be redoing this interview with current-day forest practitioners, managers and researchers. This will start with questionnaires given to all conference participants. Results will be tabulated before the end of the conference and presented for discussion on the last day. This will be followed by a mail out to a wider range of people across the boreal mixedwood region. The objective is to publish this in the Forestry Chronicle. The value in redoing this survey 25 years after the first one includes: a clear understanding in how we have progressed – which challenges have been overcome and which ones remain. More importantly is understanding why these challenges have been met or not. This knowledge will help direct research efforts and industrial resources to overcome the most important challenges. As a philosopher once stated “we need to understand where we came from to understand and direct where we are going”.
Mixedwood management for the late 21st century – what might the future hold?

Phil Comeau
Dept. of Renewable Resources, Univ. of Alberta
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While global demands and prices for wood products derived from the boreal forest have been volatile during the past decade, the development of markets for Canadian wood products in Asia and Europe is expected by many to support a strong forest industry in the boreal forest. We are also fortunate in possessing an excellent reserve of high quality spruce and aspen that can be utilized for a diversity of products. The boreal forest is globally important to carbon and water cycles and it is one of the last vast areas viewed as being largely unmanaged (despite substantial industrial disturbance). Consequently, we can expect increased pressure to conserve and maintain boreal forest ecosystems through sustainable forest management. Global interest in “close-to-nature” and “continuous cover” approaches to forest management will continue to grow through the 21st century, there are opportunities to apply these in the boreal forest, and there may be many advantages. If we can find ways to naturally regenerate spruce we could save buckets of money. Managing mixedwood ecosystems using longer rotations and taking advantage of “assisted” natural succession (ie. understory protection harvesting) may also provide a cost-effective alternative to intensive management practices.

Over the next 50 years climate change will have resulted in the southern boundaries of the boreal forest moving north, and shrinkage in the size of the forest. Warming will increase the fire risk while also increasing growth rates. Warming will also alter impacts of insects such as forest tent caterpillar, tortrix, white pine weevil, mountain pine beetle. The oil sector may have reached a stable state in terms of employment, resulting in reduced competition for workers. But our staff costs will be high, due to high wages we will need to pay to attract and keep staff. Energy costs will also be higher than they are today.

Together with a nature based (closer to nature) approach in extensively managed parts of the forest, we will likely be using more intensive management practices for the production of deciduous and conifer fibre. While monocultures might be the simplest approach – growing intensively managed mixed stands could give higher yields, better wood quality, be more attractive and acceptable, and reduce risk relating to climate, insects, fire and other issues. A number of promising and cost-effective tending practices available for creating various types of mixtures, including spot tending and aerial herbicide treatments for creating patchy mixtures. While the use of herbicides will continue, it is unlikely that this will ever be popular. The TRIAD approach will enable us to provide lumber and fibre while also accommodating an increase in protected areas and losses of productive forest land resulting from climate change and other industrial uses. Ultimately, a mix of approaches and practices will be used to maintain a diverse forest that is producing timber for commercial utilization while also satisfying increased recreational demands and meeting societies expectations that we protect biodiversity in the boreal forest. Coupled with this, the ability to measure and monitor outcomes will be substantially better due to developments in remote sensing.
Conference Sessions

**Canadian Wood Fibre Centre (CWFC):** “Working together to optimize wood fibre value – creating solutions with FPInnovations.”

**Derek Sidders and George Bruemmer**

**Who are we and our role within the Canadian Forest Service and FPInnovations:**
George Bruemmer, Executive Director, CWFC

**Overview of the CWFC Research Framework and Key Output Areas:**
Talkshow hosted by Derek Sidders, Regional Coordinator CWFC, Prairies and NWT
Speakers: Doug Pitt, Art Groot, Isabelle Duchesne and Jim Stewart

**Boreal Plains Mixedwood Fibre Initiative:**
Talkshow hosted by Derek Sidders
Speakers: Tim Keddy, Dan MacIsaac, Brent Joss and Chao Li

The Canadian Wood Fibre Centre (CWFC) brings together forest sector researchers to develop environmentally responsible solutions for wood fibre-related industries in the Canadian forest sector. The mission of the CWFC is to create innovative knowledge that will help the forest sector develop more economic opportunities from the production of Canadian wood fibre.

FPInnovations brings together Forest Operations, Wood Products, Pulp & Paper, and the Canadian Wood Fibre Centre of Natural Resources Canada, to create the world’s largest private, not-for-profit forest research institute. With over 600 employees spread across Canada, FPInnovations unites the individual strengths of each of these internationally recognized forest research and development institutes into a single, greater force. FPInnovations works toward optimizing the forest sector value chain. It capitalizes on Canada’s fibre attributes and it develops new products and market opportunities within a framework of environmental sustainability.

As FPInnovations’ main upstream research group, the CWFC specializes in creating the knowledge on the fibre resource that is critical for optimizing the forest value chain in terms of management, production and utilization of new, innovative source fibre. The principle objective of the CWFC’s research program is to maximize the economic value of Canadian wood fibre through providing industrial relevant scientific solutions at the upstream level.

The CWFC’s research is organized around two main projects: **Inventory** (forest characterization) and **Attributes** (fibre optimization). These projects support one another delivering outputs in the following areas:

**Inventory - Tools:** Inventory systems for spatially quantifying forest structure and resource and related fibre attributes to enable segregation and maximize recovery;
**Inventory - Correlations**: Techniques and methods to relate fibre attributes to tree, stand and site characteristics;

**Attribute - Production**: Techniques and methods for managing current and future forests to deliver trees and stands with specific fibre attributes; and

**Attribute – Valuation**: Techniques and methods to optimize management decisions that maximize profit and market competitiveness.

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**Canadian Wood Fibre Centre Research Framework**

This session will present the Canadian Wood Fibre Centre’s present position within Natural Resource Canada’s Canadian Forest Service and the Resource Assessment Division of FPInnovations. The core research framework and specific outputs will be described by national lead researchers and the Boreal Plains Mixedwood Fibre Initiative platform project will be profiled by the Edmonton research and development team.
Session 1a – Ecology

Natural wildfire patterns in western boreal forests.

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Detailed mortality patterns were measured on 129 historical, natural wildfires across Alberta and Saskatchewan ranging in size from 24 to almost 28,000 hectares. For each fire, negatives of post-fire aerial photos were obtained within five years of the date of the fire event, scanned at 10um, and then interpreted using six mortality classes. For 91 of those fires, pre-fire vegetation patterns were interpreted using standard provincial inventory standards and photos taken within five years of the fire event. Results reveal that 45% of wildfires have multiple disturbed patches as a result of fire “spotting” activity, the vast majority of which have a single large disturbed patch accounting for 70-95% of the fire area. Overall residual levels average 43% by area, ranging from 6-99%. No significant relationship between residual levels, and fire size, location, or local fuel conditions is evident. However, the nature of residual material is more predictable. In and near the Rocky Mountain foothills, unburned residuals tend to survive intact, and are located between disturbed patches. In the boreal plains and shield, most unburned remnant areas are partially disturbed. Pre-fire data suggest that residuals area between disturbed patches with wet soils, non-forested areas, and hardwood dominated forests are significantly less likely to burn, although residuals in the form of “islands” show no such relationship. These findings suggest that wildfire patterns are not only far more variable than previously thought, but also multi-scalar. Capturing this tremendous variability of within-fire patterns may be the next big challenge for those who wish to use disturbance emulation strategies.
Deadwood and fine litter dynamics following complete and partial harvesting of boreal mixedwood forest

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Boreal forests play an important role in the global carbon cycle. It is expected that a shift from an even-aged forest management approach towards an approach based on forest natural dynamics may have implications for deadwood and carbon dynamics. The study was set in the SAFE Project, an experiment within the Lake Duparquet Research and Teaching Forest that tests an ecosystem management model based on natural dynamics for the boreal mixedwood forest of north-western Quebec. Our objective was to compare the effects of harvesting prescriptions on fine litter and coarse woody debris (CWD) dynamics in stands of different composition and structure. We expected recruitment of deadwood to be reduced following partial harvesting while wood decomposition would increase relative to control stands. We also expected a partial restoration of C inputs through leaf litterfall with canopy closure. At various intervals after harvesting, the following were assessed: leaf litterfall by means of litter traps; volume of downed wood by triangular-transect method, fine litter and wood decomposition rates by litterbags experiment. Litterfall decreased after harvesting, reflecting residual basal area, whereas the amount of CWD, mainly small fresh debris, increased. Differences between treatments decreased with time. After 8 years, litterfall and amount of CWD showed little differences between partial harvesting and control stands. Treatments had no significant effects on decomposition of wood blocks. However, losses of masses of leaves and needles were slightly lower in clearcut. Partial harvesting differed from control in terms of the amount of snags and logs, and in terms of the distribution within decay and diameter classes. Harvesting also changed the ratio deadwood/leaf litter inputs, thus influencing the quality and mass of forest floor, which had an impact on carbon sequestration.
Aspen and white spruce productivity is reduced by organic matter removal and soil compaction

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To assess how removal of organic matter and soil compaction affect short term ecosystem dynamics, pre-treatment and year 1, 5 and 10 post-treatment soil properties and post-treatment plant community responses were examined in a boreal trembling aspen (Populus tremuloides Michx.) dominated ecosystem in northeastern British Columbia. The experiment used a completely randomized design with three levels of organic matter removal (tree stems only; stems and slash; stems, slash and forest floor) and three levels of soil compaction (none, intermediate (2-cm impression), heavy (5-cm impression)). Removal of the forest floor initially stimulated aspen regeneration and significantly reduced height growth of aspen and white spruce (Picea glauca (Moench) Voss). The compaction treatments had no effect on aspen regeneration density. At year 10, heights of both aspen and white spruce were negatively correlated with upper mineral soil bulk density and were lowest on forest floor removal treatments. Recovery of soil properties was occurring in the 0-2 cm layer of mineral soil. Bulk density values for the 0-10 cm depth remained elevated in ranges where growth reduction of tree species can be expected.
Effective Practices to Restore Soil on Previous Industrial sites in Boreal Forests
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Since 1990, several operational research trials have been conducted in Alberta forests that have evaluated the effects of equipment on soil, effectiveness of tillage practices to restore soil physical quality, and response of trees to these practices.

Depending on soil wetness and the intensity of trafficking, soil impacts are a combination of an increase in soil density and/or the destruction of soil structure to depths up to 0.60m. Destroying soil structure creates massive soil. Both impacts impair hydrologic function of soil. Traditional practices of using ripper shanks on dozers, including tooth adaptations, are generally ineffective because the soils are often wet and massive soils lack their natural structure to aid loosening. Hence, nontraditional tillage practices were developed in the early 1990s for temporary forest roads that used a large reforestation plow and dozer to plow roads to a depth of at least 0.5m and topsoil and debris were subsequently spread from the side using and excavator. The tillage produced large clods, 0.1 to 0.5m across, and large voids in the absence of further trafficking. The voids allowed the freeze-thaw process to effectively restructure the soil to the bottom of the plow pan after the first winter. Lodgepole pine seedlings were planted on an operational trial the year after tillage. After 10 years, the height and diameter of pine on plowed soil with topsoil spread immediately after plowing were significantly greater than in the adjacent cutblock where competition from aspen suckering had also been controlled. Site index was estimated to be at least 26m, which is the highest for the region. The trees showed no evidence of nutrient deficiencies. Return of the topsoil and debris was also critical to the reestablishment of the understory vegetation. The spreading of topsoil was the most expensive part of the treatment and the practice was only suitable for narrow disturbances such as logging roads in cutblocks.

In 2005, a project was initiated to develop alternative tillage practices that did not require an excavator, and would work across all industrial disturbances including wellsites. The criterion for the practice was an implement for medium sized dozers (170+ kW), plow soil to a depth of at least 0.6m, plow topsoil and subsoil in one pass while retaining most of the topsoil on the surface, and not traffic soil following plowing. The implement was designed and tested (RipPlows), which increases soil elevation an average of 0.15m. Subsequent measurements after 4 years has found that approximately 30 percent of the gain in soil elevation has been retained, which improves hydrologic function by increasing the water holding capacity of the soil, lowering a temporary watertable, and/or improving soil aeration. The practice has significantly increased growth of lodgepole pine and white spruce on plowed wellsites after four years.

Effective deep tillage improves soil physical quality for all forest vegetation on industrial disturbances, thereby demonstrating the importance of effective soil tillage practices for restoring sustainable forests on industrial upland sites.
Session 1b – Silviculture

The Effect of Physical Interactions and Understory Light Conditions on Long-term Stand Dynamics in White Spruce and Aspen Boreal Mixedwoods

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Trembling aspen (Populus tremuloides) and white spruce (Picea glauca) mixedwood forests cover a significant portion of the western Canadian boreal forest region. Both species typically establish immediately post-disturbance but white spruce grows more slowly. Over time, understory white spruce will begin to grow through the aspen canopy, at which time it is subjected to physical abrasion by aspen swaying on windy days. This, along with the reduced light levels under the aspen canopy, can significantly reduce the growth rates and survival of the spruce. This study examined the importance of physical interactions and competition for light on the growth of white spruce into an aspen canopy.

This research was conducted in Canadian Forest Service research plots established in 1951-1954 across the Prairie Provinces to determine the growth response of white spruce release from aspen. In 2001-2002, detailed tree data and hemispherical images were recorded to quantify spatial variation in understory light conditions and crown architecture. Data analysis determined the effect of current and previous physical abrasion of spruce by aspen on spruce mortality and growth. The LITE model (Comeau 2002) was used to provide an estimate of light levels in the proximity of each spruce tree; light level was then correlated with spruce survival and growth.

Results suggest that physical abrasion has a significant effect on spruce growth and mortality, resulting in a three-fold reduction in volume increment for trees with moderately to severely damaged leaders, compared to undamaged trees. Difference in growth between white spruce trees in control vs released plots accelerated since 1985, with a five-fold difference in total volume of individual trees in 2002. Linear regression of light levels with periodic spruce growth concluded that the top canopy level had the best regression fit the majority of the time and that using a grid of hemispherical images was better than stem maps. Spruce height was the best growth response variable to variations in light levels. Understory light levels had a slightly better correlation with spruce growth than the amount of canopy gaps in the overstory.

Current emphasis in boreal mixedwood management is on retaining “intimate mixtures” in residual structures (following variable retention harvest) and regenerating stands to meet a variety of ecological and management objectives. Results indicate that white spruce trees growing in close proximity to aspen are negatively influenced by physical abrasion. Stand tending operations may be required to remove these close competitors, while retaining some deciduous trees on site for ecological benefits.
Early vegetation control for the regeneration of a single-cohort, intimate mixture of white spruce and trembling aspen on upland boreal sites – 7 year results

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Two independent field studies were established to test mixedwood regeneration strategies – one near Whitecourt Alberta, the other near Timmins, Ontario. Seventh growing season data from these installations suggest that effective control of both woody and herbaceous competition is beneficial to the early growth of white spruce. Treatments that controlled only woody competition generally resulted in increased herbaceous vegetation cover and reduced seedling survival and growth. Two-meter radius treatments that controlled both woody and herbaceous competition around individual spruce planted on a 5-m grid appear to have potential for the establishment of spruce and aspen as intimate mixtures. Only in the 7th year at the Alberta site have spruce in the broadcast complete control plots started to out-perform those in the radial treatment plots. Through 7 growing seasons, aspen amongst radially treated spruce appear to have mitigated climatic extremes and reduced exposure injuries on the spruce, without significantly reducing their growth. Long-term monitoring is needed to document the dynamic interactions between these two species as the mixedwoods develop and to formulate practical regeneration strategies and crop plans for spruce-aspen mixedwoods.
Competitive effects and equivalence of woody and herbaceous vegetation in a young boreal mixedwood stand

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The first few years after planting is a critical time for establishment of planted white spruce, and understanding competition dynamics during this period can provide information useful to developing successful tending prescriptions. Resource availability (light, water, nutrients) and other ecological factor (air and soil temperature) are strongly influenced by both the type and the abundance of vegetation that develops after treatment. The Judy Creek mixedwood experiment was initiated in 2002 in Alberta to better understand the effects of woody and herbaceous control on crop tree growth. In this study we are investigating: (1) whether woody (aspen) and herbaceous (bluejoint reedgrass) vegetation have the same competitive effects on spruce growth; (2) whether relationships between competition and spruce growth change from year to year; (3) whether relationships between microclimate and spruce growth change from year to year. Results from this study indicate that: (1) aspen is having stronger negative effects on spruce growth over the 4 growing seasons (years 2-5) studied; (2) the relationship between competition and spruce growth changes from year to year (3) relationships between microclimate and growth change from year to year. Implications of these findings to mixedwood management will be discussed.
Effects of partial cutting in aspen-dominated stands on the eastern edge of the boreal mixedwood

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As a result of new forest legislation in Quebec, novel silvicultural practices will be increasingly applied on parts of the landscape in order to reduce structural and compositional differences between natural and managed forests. These practises include extended rotations, variable retention and partial cutting to maintain characteristics of older stands in a certain portion of forests. The SAFE project (*Sylviculture et aménagement forestier écosystémique*) was established in three phases from 1998 to 2000 to evaluate the degree to which alternative silviculture practices, particularly partial cutting, reflect stand-level ecological processes including forest cover succession, recruitment and mortality and to understand implications of various treatments for productivity, biodiversity and carbon cycling. Results will be presented from two phases, SAFE 1 & 3, of the experiment. In SAFE-1, dispersed light, low thinning and heavy crown thinning as well as untreated controls and clear-cuts were applied in aspen stands originating from a fire in 1923; in SAFE-3, dispersed moderate free thinning and moderate-intensity gap cuts (ca. 400 m²), along with controls and clear-cuts were applied in aspen-dominated mixedwood stands originating from a fire in ca. 1910. Residual growth, mortality and sapling recruitment over ten years following treatments will be presented. Configuration, intensity and size-class selection of partial cutting treatments as well as understory presence of competitive shrub species and advance regeneration, influence short-term responses in these mixedwood stands.
Session 2a Growth and Yield

Volume yield of Norway spruce (*Picea abies* (L.) Karst) and downy birch (*Betula pubescens* Ehrh) grown in mixed or pure stands under Boreal conditions

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In 1973 a field experiment was established to quantify the effect of growing birch and spruce together, in a mixed birch-pine shelterwood with about 2000 stems ha$^{-1}$, a height of about 13 m, and a standing volume of about 130 m$^3$ ha$^{-1}$. There was about 3000 stems ha$^{-1}$ of Norway spruce beneath the shelterwood, with a height of about 2-4 m. The experiment had 14 plots of 0.1 ha, each surrounded by a 5-10 m wide buffer zone with the same treatment as the net plot. The treatments were dense (B6 = 600 stems ha$^{-1}$), sparse (B3 = 300 stems ha$^{-1}$) or no birch shelterwood, combined with no (zero,) or 1500 stems ha$^{-1}$ spruce undergrowth (S), resulting in a total of five combinations – B6, B3, B6S, B3S, S. After treatment the shelterwoods consisted of 96% birch and 4% pine. The experiment was unbalanced, i.e. the number of replicates differed between treatments, such that there were two replicates for all treatments except S and B6S, which had four replicates. Height/diameter-ratio of Norway spruce was significantly affected throughout the observation period, such that the spruces became increasingly slender with more birch shelter trees (p<0.05). Total volume production of Norway spruce during the observation period was not significantly affected by the presence of birch shelter trees, but the total volume production of birch was significantly lower when an under-storey of spruce was present.
Are mixtures of white spruce and trembling aspen more productive than pure stands?

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Man and Lieffers (1999) reviewed several mechanisms of interaction between white spruce *Picea glauca* [Moench] Voss) and trembling aspen (*Populus tremuloides* Michx.). They concluded that competition between these species could be reduced by several mechanisms, including differential shade tolerance, physical separation of canopies, phenological differences or differences in soil resource utilization. Furthermore, they suggested that aspen could facilitate the growth of white spruce through improved litter decomposition and nutrient cycling, amelioration of environmental extremes, and control of shrubs, grasses, and pests. As a result, they considered it likely that mixtures of these species could yield more than pure stands. This possibility has not been tested to date, however, and the effect of species composition on white spruce and aspen productivity remains uncertain.

We examined this question in 20-year-old stands located near Thunder Bay, Ontario. Earlier vegetation management treatments had resulted in a range of composition from pure spruce to pure aspen, with varying degrees of mixture in between (Bell et al. 2011). Site occupancy, stand stem volume growth, and aboveground tree biomass growth of softwoods (predominantly white spruce) and hardwoods (predominantly trembling aspen) were measured in 45 154 m² (7 m radius) temporary sample plots within these stands to examine the effects of species composition on forest production. Measures of site occupancy derived from Plant Canopy Analyzer data indicated that sample plots were fully occupied, and leaf area index and light interception increased with increasing softwood (SW) proportion. The form of the relationship between site occupancy and SW proportion differed among occupancy metrics, suggesting that basal area, stand density index, and crown area index do not adequately represent use of the light resource. No significant effect of species proportion on volume or biomass production was detected, contradicting the hypothesis that competitive reduction and facilitation might increase the production of mixed spruce-aspen dominated stands.


Static and dynamic limits for maximum biomass – density relationships in boreal mixedwoods

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We examined maximum size-density relationships (MSDR) of pure and mixed stands of trembling aspen (Populus tremuloides Michx.) and white spruce (Picea glauca (Moench) Voss.) by using data from permanent sample plots from the boreal forest natural region of Alberta, Canada. Mean tree biomass – total density relationships were analyzed by using stochastic frontier function regression and mixed models to determine both the static and dynamic limits, respectively, and to test for the effects of site quality, age and stand composition. A steeper slope was obtained for the dynamic than for the static limit, although both values were significantly different from the hypothetical slope value suggested by the self–thinning law. Nutrient regime and stand composition appeared to affect the slope and the intercept for both limits. Results suggest that a multi-dimensional surface response seems to be more appropriate in explaining maximum size-density relationships for boreal mixed stands as it has been suggested in previous studies for other tree species, and that the theoretical value of the self–thinning law could be considered as an ‘average’ value with variations due to variations in site characteristics.
Management for multiple values/purposes in the boreal mixedwoods requires the identification of different value options determined by various utilization strategies and/or management operations, and the valuation of these value options to support optimal decision making for achieving the goal of sustaining forest resources without losing opportunities of regional economic development. This management goal has been increasingly emphasized in recent years to promote a balanced approach in the utilization of forest resources and the conservation of forest ecosystems. In addition to meeting requirements from forest product industries, this approach also reflects the requirements from the perspectives of green environment and social acceptability in managing our natural resources. Realization of this balanced approach needs a great effort in integrating research results and techniques from various disciplines including ecological, environmental, social and economic considerations, etc. One of the major challenges in implementing multi-purpose forest management is deciding on the best utilization which relies on valuation of forest resources. A single value for a given forest is usually required and results from conventional forest valuation. In multi-purpose forest management, however, different values could result from various strategies of utilization such as solid wood, pulp and paper, biomass and bio-energy, carbon storage and potential credits, and other forest ecosystem goods and services. Though the complexity in decision-making for multi-purpose forest management is increased, it appears closer to real scenarios of forest management towards the maximization of total benefits from available wood supply. In this presentation, a new method of inventory valuation will be described which recognizes that values for a given inventory may vary with utilization strategy and product market conditions. This integrated information system (a prototype of WFVSM, standing for Wood Fibre Value Simulation Model) was developed to link from forest inventory, to supply chain costs, and to market price. The integrated information system could assist forest resource managers and planning practitioners to valuate their inventory by different value options and associated production costs, for the purpose of determining the best utilization strategy under their product market situations. Examples of applying this computerized information system will be presented to show the costs and time saving in data analysis. Challenges and future research needs for improvement of the inventory valuation will also be discussed.
Exploring synergetic nexus between sustainable forest ecosystem management and technological progress in regionally segmented Canadian logging industries: *Normative Analysis and Nonparametric Modeling Approaches*

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The concept of sustainable ecosystem management is being publicized and strategic institutions – “rules of the economic game” – are being developed and implemented. The goal of this study, which is in its final stages, is to explore synergetic nexus between sustainable forest ecosystem management (SFEM) and total factor productivity (TFP) in regionally segmented Canadian logging industries of British Columbia, Ontario, Quebec, and the rest of Canada. We hypothesized that if logging firms had adhered to the cardinal-normative rules of SFEM and technological progress was attained through enhanced investments in R&D that caused TFP growth, then, logging operations might have been characterized by: technical efficiency; minimum bio-ecological and environmental damages; implementation of the cardinal rules of reduced impact logging; tolerable of the inevitable decline in: forest ecosystem health, biodiversity, and environmental quality; and firms in each regional industry had comparative cost advantages. We have illustrated this hypothesis schematically with a *virtuous cycle* diagram.

Divided into two parts, this is a comprehensive study. The normative analysis approach in Part I covers the following: the technical and ecological challenges associated with logging; the concept and guidelines of reduced impact logging; the institutional imperatives of forest policy; the concept of adaptive co-management; the precautionary principles approach; the value chain of harvested timber in fully integrated processing firms; and much more concepts that promote SFEM. In Part II, measurement and analysis of TFP is underway. The production technology was specified as a function of capital, labor, energy, and materials. The theoretical framework was written; the *translog* multilateral index model for the nonparametric analysis was formulated; building and diagnosing the database were completed; and preliminary empirical results were generated. The overarching concepts, some preliminary findings of the empirical work, and policy relevance of this study will be presented at this conference.
Similarities and differences between natural post-fire and post-harvest regeneration on upland sites in Alberta: what does this mean for the future?

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Upland sites in the western boreal mixedwoods are largely dominated by fire origin stands with varying proportions of white spruce and aspen. After white spruce stands are harvested they are most often regenerated by planting, due to the unreliability of natural regeneration. Comparisons of stand structure and composition between post-wild fire and post-harvesting stands are important for predicting how the mature boreal mixedwood will be structured in the future. We investigated how the pre-disturbance composition influenced composition and structure of post disturbance regeneration and compared post-fire and post-harvest mixedwoods.

We assessed regeneration in five fires on upland sites of the boreal mixedwood region in Alberta. Pre-fire stand types were identified based on Phase III Forest inventory maps and divided into four groups 1) pure conifer (white spruce), 2) conifer leading mixtures, 3) deciduous leading and 4) pure deciduous. Post -harvest regeneration data were obtained from a previous study and from forest companies. Post fire assessment was based on the same performance age assessment protocols as used by the companies. The data were collected so that we could analyze the differences in stocking, density and height of tree species.

For deciduous-dominated stands, pre- and post-fire composition was similar. However, there were significant differences from pre- to post-fire composition for stands that were conifer dominated before disturbance. We also found significant differences in conifer stocking between post-fire and post-harvest stands. Only 30% of the post-fire conifer plots were stocked with at least one conifer ≥30 cm tall compared to 82% of the plots in the post-harvest stands. This number rose to 93% if the plots had also been tended (mechanical brushing or herbicide spray). In the plots that were both planted and tended, 47% were stocked with a deciduous tree. Out of the post-fire plots, 72% were stocked with a deciduous tree; this climbed to 93% of the non- tended plantation plots. Only 1% of the plots in post-harvest plantations were not sufficiently restocked but this number increased to 21% of the post-fire plots in stands that were conifer dominated before fire. The conifer densities were highest in 1) post-fire stands (7073 trees/h), 2) tended plantations (4627 trees/ha), and 3) non-tended plantations (4118 tree/ha). Surprisingly, in the post-fire stands, only 307 trees/ha were white spruce and the rest of the conifers were pine. Stands that were previously conifer dominated mixedwood were often stocked with deciduous trees. The highest deciduous densities were found in 1) untended plantations (11354 trees/ha), 2) natural post fire stands (9119 tree ha) and 3) tended plantations (3049 tree/ha). However, planted spruce were significantly taller than those that had regenerated naturally. Poplar species were taller in non-tended plantations but there was no difference between the tended and the naturally regenerated poplars in the pre-disturbance conifer dominated stands.
We will use this early structural information to model the mature forest structure using the Mixedwood Growth Model (MGM) to evaluate what legacies early starting conditions have on the resilience of the structure and composition of boreal mixedwoods on upland sites.

**Session 3a – Mixedwoods and Global Change**

**What of climate change for the boreal mixedwoods of Canada?**

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Debate about the reality of climate change, its magnitude and its potential impacts, has got to the point where any signals have been almost obliterated by the noise. Can we glean anything useful from projections of future climate that will help us make better decisions concerning the future management of forest resources, in spite of the many uncertainties? Scenario analysis is a technique that can assist with decision-making in long-term forest management planning. Focusing on the boreal mixedwoods of Canada, I will report on downscaled past climate observations and future projections to attempt to summarize what we know, what we may be reasonably certain of, and what is possible but by no means certain.
Moisture cycles and trends in Alberta forests

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Global climate change is generally perceived and expressed as rising average temperatures. Changes in precipitation, runoff and soil moisture are at least as important, especially where availability of water limits economic and ecologic productivity, such as in Canada’s western interior. The trends projected by climate models may be emerging in streamflow records that integrate the water balance over large areas. Trends are less apparent in other hydroclimatic variables, where there is small ratio of signal to noise. The noise is dominated by strong interannual and decadal variability. It is most apparent in instrumental records of winter precipitation and snowmelt runoff, and in our tree-ring reconstructions of annual hydroclimate for the past millennium. Because large-scale ocean-atmosphere oscillations largely determine the tempo and magnitude of drought and excess moisture, the impacts of global warming on forest productivity will depend on changes in these teleconnections between warming oceans and precipitation over western North America.
Challenges in assessing drought impacts on boreal aspen and mixedwood stands in western Canada

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Drought-induced forest decline has emerged as a major risk for the future of forests around the world under a changing climate. Analyses of the climate record in western Canada indicate a significant warming trend (>2 °C) over the past century and a pattern of severe, rotating droughts has affected large areas of the region since the late 1990s. This raises concerns, based on model projections of a northward movement of prairie-like climates during this century. In 2000, our research group established CIPHA, a regional-scale study aimed at tracking climate-related changes in pure, mid-aged (40-90 year old) aspen stands across the boreal forest and adjacent parklands of west-central Canada. The CIPHA study includes annual monitoring of tree health within a network of 180 plots, along with periodic tree measurements and tree-ring analysis. The hierarchical study design of CIPHA is aimed at “scaling up” tree-level measurements to provide early warning of climate-related impacts on the region’s aspen forests. Early results from the CIPHA study showed that drought and insect defoliation are the most important factors affecting productivity, dieback and biomass increment of aspen forests in western Canada. During 2001-2002, an exceptional drought affected the CIPHA study region and led to massive mortality of aspen across the parklands of Saskatchewan and Alberta.

Analyses of CIPHA measurements showed that this drought led to a multi-year, regional collapse in aspen stand biomass increment due to a tripling of stem mortality and a 30% decline in growth. Anecdotal observations indicate that many other forest types have also been affected by recent droughts, but to date, this has been poorly documented in our region for species other than aspen. Tree-ring studies show that drought exerts comparable impacts on the growth of major boreal conifers in our region, but most of these studies were conducted in stands dominated by a single tree species. Thus a knowledge gap remains as to how drought affects the dynamics of closed-canopy mixedwood stands that are an important component of the managed boreal forest. Based on preliminary tree-ring studies at boreal mixedwood sites in Saskatchewan, Alberta and Yukon, we have identified several inherent challenges, including a) differences in tree species responses and b) competition across height classes and species which leads to high variation in growth among trees. Thus, large sample sizes are needed to obtain statistically reliable estimates of climate effects on growth at the stand level. Furthermore, the assessment of drought effects on mixed wood stands is often confounded by the impacts of insects that preferentially target certain tree species, for example forest tent caterpillar defoliation of aspen and spruce budworm defoliation of white spruce. Insects may also exert indirect effects such as growth releases of understory spruce during years when the canopies of aspen-dominated stands are severely defoliated by forest tent caterpillar. Despite the challenges, an enhanced understanding of drought effects on mixed-species stand dynamics would provide valuable insights for reporting on and adapting to the climate-related changes that have already been documented in the forests of our region.
Trembling aspen competition, climate, and site preparation effects on white spruce growth in boreal forests of Western Canada

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In this first study, we investigated the combined effect of trembling aspen competition and climate on white spruce growth using data from a long term study with matching treatments spread across the boreal mixedwood forests of Alberta and Saskatchewan (Canada). Results indicate that competition (i.e., aspen basal area), initial size of the tree and mean annual temperature account for 88% of the annual variation in spruce volume growth for these six locations. Based on our model, spruce growth, in the absence of competition, is estimated to increase by up to 17% as mean annual temperature increases from 2° C to 3.3° C; while, at high levels of competition (aspen basal area = 27 m² ha⁻¹), spruce growth increases by only 8%. Moreover, effects of aspen on spruce growth increase more than proportionally as mean annual temperature increases. This outcome indicates that abundant aspen competition affects the spruce responses to rising temperature, presumably due to competition for light and potentially increased competition for soil resources. Results also show that competition and climate effects vary between locations, indicating that spruce growth is strongly influenced by other local factors such as micro-climate, topography, and soil properties.
Session 3b – Stand Dynamics

Effect of competition on retrospective stem growth of white spruce and trembling aspen at mid-rotation age in western Canadian boreal mixed forest

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Intra- and inter-species competition plays an important role in affecting forest growth, composition, structure, and succession. In many forests, including the western boreal region, the upland forest is characterized by a mixture of tree species, where intense intra- and inter-species competition occurs during stem exclusion stage, i.e. 25–80 years of stand age, but our understanding of growth-competition relations during this stage is still lacking. For sustainable forest development, therefore it is critical to quantify the effect of competition on forest growth in the mixed boreal forest ecosystem during this stage. In this study, we investigated and quantified the effect of competition on stem growth of the two predominant species, white spruce (*Picea glauca*) and trembling aspen (*Populus tremuloides*) during this stage. We surveyed the boreal mixedwood region of Alberta using an efficient sampling technique which combines traditional approaches of collecting competition data (fixed and variable radius plots) with dendrochronology for stem growth data. Different competition indexes including stand basal area, the sum of stem diameter at breast height, and density for the broadleaf and coniferous species, as well as similar indexes considering only trees thicker than each subject, were evaluated. We used a nonlinear mixed modeling approach to model the average ring-width and basal area growth over recent 5, 10, 15, 20, 25, 30, and 35 years as the function of competition-free ring-width and basal area growth from nearby dominant trees, initial sizes of the nearby dominant trees and of subject trees, deciduous and spruce competition indexes, and ecoregions. The nonlinear model fit the data well. Our results confirm findings previously obtained from provincial Permanent Sampling Plot (PSP) data, but also show that basal area growth is a better growth variable than ring-width for both species, and the competition index using the diameter at breast height of thicker trees is a superior predictor than any other competition index. Our results demonstrate that current competition can have long-lasting effects on stem growth, as the best models integrated growth for 15 years for aspen and 20 for spruce. The dendrochronological approach is an efficient tool to investigate species competition relation in the boreal mixedwood forest. Our results will be integrated into the Mixedwood Growth Model (MGM) to more precisely predict forest productivity in the western Canadian mixed boreal forest.
Modeling juvenile aspen-spruce growth dynamics: Preliminary results from the Dynamic Aspen Density Experiment (DADE).

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Informed and efficient management of the aspen-spruce mixedwood forest complex requires a quantitative understanding of the growth characteristics of juvenile aspen-spruce mixes. The ability to project future stand development of juvenile aspen-spruce forests under different management regimes will allow practitioners to assess silvicultural options, to implement short- and long-range plans that achieve management objectives, and to demonstrate ecological sustainability.

Such a complete quantitative understanding does not currently exist for Alberta’s aspen-spruce forests. To address this gap, the Mixedwood Management Association of Alberta initiated the Dynamic Aspen Density Experiment (DADE), a long-term project to collect quantitative stand development data in young aspen-spruce stands.

DADE Objectives are to:
1. Identify the thresholds in aspen density that determine Stand Condition (Symbiotic, Commensal, Competitive) during each of two Stand Development Stages (17 and 22 years of age).
2. Determine the survival and growth of white spruce and aspen in different Stand Conditions during each of two Stand Development Stages.
3. Determine the opportunity cost to aspen production of optimizing spruce survival and growth.
4. Provide credible data with which to evaluate and improve the Reforestation Standards of Alberta for mixtures of aspen and spruce.
5. Provide robust data for improvement of Alberta’s existing stand-level forest projection models (Mixedwood Growth Model (MGM), Growth and Yield Projection System GYPSY).

Using permanently marked and remeasured experimental treatment units in a randomized complete block design, tree survival and growth for prescribed densities of aspen and spruce in different mixtures are being tested. To date, fourteen permanent installations have been established, with three-year results available for nine installations.

Post treatment stand conditions are used to seed MGM and GYPSY stand projection forecasts, and three year second-measurement results are used to test those projections.

Detailed project design, methods, analyses, results and management implications are presented.
Long term analysis of the effect of release treatments on the total volume of central mixedwood stands: a carbon perspective.”

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The Canadian boreal forest represents approximately one third of the total boreal forest around the world and represents more than 15% of the total terrestrial carbon (C) pool. Boreal forests are important to the global C cycle because they store huge amounts of C in their soils (representing more than 50% of the soil C of the world) and exchange C with the atmosphere through photosynthesis and respiration, release C following natural and anthropogenic disturbances and because they can become sinks of C under certain management practices. Boreal mixedwood forests are widely recognized as being important in carbon capture and storage. Several studies suggest that aboveground production of tree biomass should be greater in mixed stands compared to pure stands. However, without tending the abundance of aspen in young and mid-aged stands can substantially reduce growth of white spruce. Consequently, stands are often tended and aspen are removed or reduced in abundance when the objective is to grow spruce or spruce dominated mixtures. Such release treatments generally lead to pure stands and may have impacts on carbon sequestration and storage.

We evaluated the productivity of mixed hardwood – white spruce stands compared to released stands of white spruce across central Saskatchewan and western Manitoba. Stands of age 25-50 with understory white spruce and overstory hardwoods had hardwood removal treatments in 1936 or 1951-1954 by the Dominion (now the Canadian) Forest Service. Permanent sample plots were established in treated and control areas at that time and remeasured periodically up until 2010.

At the time of maximum average production (~2001), there was slightly more volume in the mixed control stands. However, the spruce volume in released stands responded strongly and nearly made up for the loss of hardwoods. Treatments which achieve pure spruce stands appear to achieve levels of live biomass similar to those of untreated stands over the long term. We will present results of modeling the other carbon pools using the Canadian Forest Service Operational Scale Carbon Budget Model and discuss these results in terms of ecosystem carbon in mixed and pure stands.
White Spruce Understory Protection
From Planning to Growth & Yield Implications

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A large component of the boreal mixedwood forest is comprised of aspen and white spruce in mixes of varying proportions and ages. The slower growing white spruce starts as an understory component but will succeed to a white spruce dominated stands after aspen break-up. Since both species are utilized by the forest industry, one way to maximize yield is to protect the white spruce understory while harvesting the aspen overstory. This is achieved by restricting machine traffic to designated trails, allowing the buncher to reach to either side to extract the aspen, leaving the spruce undisturbed. An un-harvested buffer strip is usually maintained between the extraction areas to protect spruce from blowdown.

Although some of the spruce understory is lost on the machine corridors, future conifer yield is augmented by the release or growth acceleration of the protected spruce component due to increased light levels. Since understory protection has only been practiced for less than 20 years in Alberta, long term data on post understory protection stand development are not available. In order to account for the yield implications in timber supply analysis, accurate forecasts of future stand development can only be obtained through the use of a forest growth model. The Mixedwood Growth Model (MGM) has a unique architecture that allows modeling of various strata in understory protection stands. This “multi-strata” modeling approach forecasts the combined yield of all the strata, including the impact of adjacent strata with regards to light availability.

Operational examples of understory protection, data on while spruce release and aspen regeneration as well as modeled volume forecasts will be presented.
Session 4a – Beyond Breakup – Dynamics of old boreal aspen and mixedwood stands

Traditionally, succession in boreal aspen or mixedwood stands was considered to be a gradual replacement of aspen by more shade tolerant conifers over time. Our understanding of mixedwood dynamics has expanded with the recognition of variability within initial stand conditions, neighbourhood effects and intermediate disturbances combining in multiple potential pathways. For aspen dominated stands, long term succession in the absence of fire has been particularly speculative with little documentation. Recent new data has described gap phase dynamics and a variety of regeneration trends occurring in older aspen dominated stands.

In this session we will provide examples of research in aspen and aspen dominated mixedwoods from Quebec, Manitoba and Alberta which describe successional dynamics well beyond the time frames we usually associate with aspen. The closing presentation will describe how research results for old aspen dominated stands have been incorporated into Forest Management Plans for the Duck Mountain Provincial Forest of Manitoba.
Forest succession and gap dynamics in boreal aspen and mixedwood stands following a forest tent caterpillar outbreak in north-western Quebec.

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Forest tent caterpillar (FTC, Malacosoma disstria) outbreaks represent one of the most significant secondary disturbances in deciduous and mixed boreal forests dominated by trembling aspen (Populus tremuloides). To describe the effects of such a disturbance on forest stand succession and gap dynamics, we studied 20 deciduous stands and 12 mixedwood stands situated on well drained clay soils in the balsam fir-white birch biogeographic domain of western Quebec, 5 and 6 years respectively after the last outbreak (1998-2003). To characterize the response of forest cover, line intersect transects were run in stands that had undergone different defoliation regimes in terms of number of years and defoliation severity. To study tree replacement and stand dynamics following FTC disturbance, gaps and regeneration were characterized along the same gradient of defoliation regimes. Our main results indicate that canopy opening and mean gap area increased significantly with disturbance intensity in both deciduous and mixed forests. In deciduous (pure aspen) stands, aspen recruitment increased proportionately with defoliation intensity and gap size, thus signaling aspen resilience following FTC defoliation. In mixedwood stands, aspen regeneration was not positively affected by defoliation intensity and gap size, whereas recruitment and apical growth of conifers (mainly balsam fir (Abies balsamea)) were higher following FTC defoliation; recruitment was higher in small gaps and apical growth was superior in large gaps. From a successional point of view, secondary disturbance such as FTC outbreaks in deciduous forests create a wide range of deciduous stands, including uneven-aged structures, and tend to prolong the deciduous phase, whereas in mixedwood forests, FTC outbreaks tend to accelerate the conversion of mixed canopies to a coniferous or conifer-dominated mixed stage by shortening the duration of the aspen-dominated mixed phase. However, further monitoring of such disturbed aspen and mixedwood stands is required to evaluate the response of residual canopy trees and assess the consistency of regeneration patterns and forest succession pathways in the long term.
Long-term direct observations of old-growth boreal mixedwood forest stand dynamics in west-central Manitoba

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This study summarizes direct observations on the long-term dynamics of boreal mixedwood forests of the Forest Experimental Area, Riding Mountain National Park, Manitoba. These forest stands consist primarily of trembling aspen and white spruce, with lesser amounts of balsam poplar. A set of 266 disturbance-free, 20 x 20 m permanent sample plots established in 1946-1948 (stand age = 120 years) was monitored over a 55-year period (1947-2002, stand ages = 120 to 175 years) to determine changes in forest stand composition, structure and biomass. Forest stand composition and structure varied in 1947 (stand age = 120 years), leading to the recognition of four initial physiognomic groups: A = mature hardwoods, delayed softwood recruitment ($n = 43$); B = mature and regenerating hardwoods, delayed softwood recruitment ($n = 35$); C = mature hardwoods, contemporaneous softwood recruitment ($n = 118$); D = mature and regenerating hardwoods, contemporaneous softwood recruitment ($n = 70$). In the group A plots, hardwood abundance was maintained over time through the successful recruitment of a second cohort; softwood recruitment was continuous. By 2002 (stand age = 175 years), most of these stands were co-dominated by trembling aspen and white spruce. In the group B plots, the hardwood regeneration (second cohort) already present in 1947 had reached the canopy by 2002; softwood recruitment was continuous. In 2002 (stand age = 175 years), most of these stands were co-dominated by trembling aspen and white spruce. In the group C plots, successful recruitment of a second cohort maintained hardwood abundance in about half of the plots ($n = 57$), but a second hardwood cohort failed to develop in 61 of the plots. In all plots, softwood recruitment was continuous. By 2002 (stand age = 175 years), about half the stands were co-dominated by trembling aspen and white spruce, while the other half were dominated by white spruce with a secondary hardwood component. In the group D plots, the hardwood regeneration (second cohort) already present in 1947 had reached the canopy by 2002; softwood recruitment was continuous. In 2002 (stand age = 175 years), most of these stands were co-dominated by trembling aspen and white spruce.

The results of this long-term direct observation study offer little support for stand dynamic models hypothesizing the temporal replacement of hardwoods by softwoods in boreal mixedwood forests. Hardwood regeneration (establishment of a second cohort) was successful in most plots, and this served to maintain a mixed hardwood-softwood composition at 175 years of age. In 2002 only 21.8% of the plots were softwood-dominated (i.e. > 80% basal area), while 16.5% remained hardwood-dominated. The long-term persistence of hardwoods in these stands is attributed to the clonal regenerative ability of trembling aspen and balsam poplar, and possibly to competition from the tall shrub beaked hazelnut that limits white spruce recruitment.
Incorporating multi-cohort old aspen and mixedwood dynamics into a long term forest management plan

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The majority of forest stands in the Duck Mountain Provincial Forest of Manitoba are old stands, with inventory estimated ages of 80 to 120 years old. Yield curves were constructed from stratified random sample plots aged 40 to 120 years old. Modeling the Future Forest Condition of today’s old stands 200 years into the future was a significant challenge as part of a Sustainable Forest Management Plan. Forest habitat elements (e.g. stand structure, snags, and coarse woody debris) were modeled in addition to stand volume.

1,500 Permanent Sample Plots (PSPs) were established in Riding Mountain, Manitoba in 1946 by the Dominion Forest Service in stands aged 120 to 150 years old. Remeasurements occurred in 1951, 1956, 1961, 1966 and 1969, and were further supplemented by measurements funded by LP Canada in 2002. This effort yielded 50 years of remeasurement data from stands now aged 170-200 years old. The quality and amount of data in the Riding Mountain National Park PSPs represent the best available in Canada.

These data were analyzed to develop general successional trends. The analysis of the PSPs showed clear evidence of gap-phase dynamics that renewed and maintained aspen and mixedwood multi-cohort stand canopies. Pure aspen, older forests maintained themselves at lower than maximum volume. In mixedwoods, forests canopies gradually increased in conifer associated with small openings and increased in aspen occurring in larger openings. Also average tree age varies as time since disturbance lengthens; and stand volume gradually rises and falls in association with canopy gaps opening and closing.

The recent discovery of multi-cohort aspen and mixedwood stands was incorporated into modeling the Future Forest Condition of the 2006-2026 Sustainable Forest Management Plan for the Duck Mountain Provincial Forest. These stand dynamics replaced previous modeling assumptions of even-aged stands ‘breaking up’ and suffering catastrophic loss (i.e. death age) where volume equals zero at stand ages 140-160 years old. Modeling the multi-cohort stand dynamics resulted in a significantly different Future Forest Condition due to: maintenance of a continuous forest canopy over the entire landscape; higher biodiversity in older stands due to multiple canopies, abundant snags, and coarse woody debris; and avoidance of a large age class imbalance due to stands being available for harvest longer, but at a lower volume.
Modeling Long-term Productivity and Successional Pathways of Aspen in Alberta

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In this study, the long-term productivity of aspen was modelled based on the repeatedly measured permanent sample plot (PSP) data collected across Alberta’s boreal forests. Both total and merchantable volumes were used to indicate the long-term productivity. The impacts of site quality, competition, species interaction and ageing on the long-term productivity of aspen were evaluated. Relationships between the productivity and other factors were established. Results showed that, in spite of the common beliefs that aspen matures in 60 to 80 years, lives only a short time of up to 80–100 years, and succeeds to white spruce in most cases, many older aspen and mixedwood stands (>100 years) continue to maintain a significant portion (25%–50%) of aspen volumes well over 100 years, rather than succeeding to white spruce and other conifers as expected.

In order to understand the potential reasons why a significant portion of aspen productivity was still maintained after 100 years, the successional pathways of aspen growing in boreal mixedwood stands in Alberta were examined. The long-term changes in aspen species composition were modeled. The spatial distribution and the diameter distribution of all live aspen stems were assessed. Results showed that spatial gaps were created in these stands by the uneven natural mortality of the first aspen cohort originated post-fire. A gradual replacement of the first aspen cohort by successive waves of aspen recruitment cohorts was common in many of these stands. This was likely a result of the gap disturbances, which, coupled with the poor ability of white spruce to quickly fill-in the gaps, allowed the fast growing aspen to rapidly re-establish dominance after the disturbances. This produced multi-cohort aspen trees in the stands rather than a simple replacement of aspen by white spruce as commonly thought. It could explain why the productivity of aspen was maintained long after the aspen trees were supposed to die and the stands were supposed to succeed to white spruce stands. It could also explain why the boreal forests acted like a dynamic moving mosaic in the long-term, as the spatial and temporal distributions of the gaps and subsequently replacement of these gaps were controlled by the original distribution and mortality patterns of the first aspen cohort and the accompanying white spruce component. The results obtained in this study may be used to guide new forest management practices aimed at maintaining and mimicking the long-term ecosystem productivity of aspen in boreal mixedwood stands in Alberta.
The Mixedwood Growth Model (MGM), an individual tree, distance-independent forest growth model, has been routinely updated since the 1980’s as permanent sample plot and other data have become available in the western boreal region. In this session we describe the structure and use of MGM, recent and on-going enhancements to its growth and mortality functions, and validation for pure and mixed-species stands in the western boreal forest region.

Enhancements to MGM include a facility to stratify stands into different structural types, and develop composite yield curves with and without considering the effects of adjacent stand structure. This feature is particularly useful in modeling the fine spatial structure of strip-cuts for understory white spruce protection. Validations include various sources of PSP and dendrochronological data, including >60 year spruce release treatments. Post-fire regeneration data demonstrate that MGM recovers similar yields as natural origin stands. We highlight the release response of white spruce, and demonstrate how MGM models highly structured stands.
Quantifying Local Effects of Deciduous Competition on White Spruce Height Growth and Site Index in the Western Boreal

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Our study evaluated white spruce (*Picea glauca* [Moench] Voss) height growth potential on sites released from deciduous competition. Previous studies of white spruce productivity ignored inter-specific competition that usually occurs between spruce and deciduous species in young to mid-aged stands. We used plots established by the Canadian Forest Service in the 1930’s and 1950’s in mixedwood controls and aspen removal treatments across the mixedwood boreal forest in Saskatchewan and western Manitoba. Detailed stem analysis, plus re-measurement data from these trials were used. Our results showed that release response was site-specific; i.e. varying from -19 to 46% in spruce site index (SI, height at breast height age 50). Overall, the interpolated site index of released spruce was not significantly increased due to a late application of release treatments. However, height increment 50 years following treatment was elevated by 2.1 m and post-release growth rate was matched by a 4.1 m higher site index. Existing height-age equations for this region showed varying suitability. Investigating deciduous competition in relation to the degree of release indicated that the amount of deciduous basal area removal accounted for significant site differences. Gains of up to 6 m in site index over mixedwood spruce were observed, and our model indicated a potential 7 m gain from early release from heavy competition. This study provides a first long-term estimate of the degree that spruce height growth from mid-age to maturity can be increased by deciduous competition removal.
Impact of variable broadleaf density on spruce growth near Dawson Creek and Fort Nelson in northern British Columbia

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Paper birch (*Betula papyrifera* Marsh.) and trembling aspen (*Populus tremuloides* Michx.) occur across a wide range of ecosystems and may be found at all latitudes in British Columbia (BC). The presence of broadleaves in conifer forests may contribute to species and structural diversity, accelerate nutrient cycling, reduce insect and frost damage, reduce competition from understory vegetation, and increase total yield compared to pure conifer stands. However current BC forest regulations drive regeneration management towards pure conifer stands rather than promoting a mixed-species condition. Therefore in early stand development most broadleaf species are routinely removed from the managed stand to ensure successful conifer regeneration and growth. This approach may result in unnecessary vegetation control across the province. On the other hand, more has been learned about the role of broadleaves in forest ecosystems but specific knowledge concerning competitive interactions of mixed broadleaf–conifer stands is still scarce. To develop effective management strategies for broadleaf–conifer mixtures where softwood timber production is the primary objective, silviculturists may require information about the level of broadleaves that can be retained without seriously affecting conifer performance. A competitive interactions study was conducted in northern British Columbia to facilitate ecosystem-specific management for spruce and broadleaf species (birch or aspen). In 2007, temporary sample plots were installed at all three sites to collect species-density relationship data across a range of early stand conditions and ages. Growth of spruce was measured under varying densities of birch or aspen. It appears that birch or aspen has not had a deleterious impact on spruce radial growth during early stand development. This was reflected by similar crop tree DBH across a range of stocking densities or competition indices. After two years of growth, there was a significant negative relationship between mean annual DBH growth and the competition metrics. At establishment the relationship between spruce crop tree DBH and aspen or birch density, RDI (relative density index) or SDI (stand density index) were negative but the regression was not significant. Mean annual DBH growth was the same at 0 (control), 1 and 2 m brushing radii and only increased at the 4 m brushing radius except at one site. The results suggest that instead of encouraging uniform removal of aspen from spruce plantations mixed species management could enhance forest productivity and diversity up to a yet to be determined broadleaf density threshold.
Sprouting from shallow roots is a dominant means of regeneration of aspen following disturbance that kills mature trees. In this presentation we examine several features that are thought to be important in the sucker regeneration and growth of aspen: 1) Warm soils promote growth of suckers, but once soils are above ~9°C there is little difference in the number of suckers that are initiated by the roots. Soil temperature, however, does affect how many of these suckers reach the soil surface and get exposed to light. 2) Winter logging is thought to be the best time to log because root carbohydrates are thought to be at their maximum. In reality, however, a fall flush of root growth consumes most of the stored carbohydrates. If soils and root systems are not disturbed, there is no difference in sprouting between summer and winter logging or mechanical brushing. 3) Root wounding can stimulate suckering, but wounding is also associated with increased root diseases and most of these suckers have low vigour and fail to reach the surface. 4) Soil compaction and reduction in root aeration limits growth of aspen more than most other species. 5) A stimulating agent for suckering is NO$_3$. NO$_3$ is more commonly available than NH$_4$ following fire or in conditions of rapid decomposition (warm and moist soils). In summary a conceptual model of aspen suckering regeneration is presented.
Posters

Evaluation of stand and tree level responses to partial cutting in boreal mixedwood, using experimental and modelling approaches

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Understanding stand dynamics is important for forest conservation and management. The eastern boreal mixedwood forests are generally associated with productive, mesic sites and represent a transitional, post-fire stand development phase between break-up of an initial cohort of intolerant hardwoods and dominance by late-successional species. In mesic sites, aspen frequently dominates stands with white spruce and balsam fir. It is expected that partial cutting will be increasingly applied in mixedwood stands, particularly where the intolerant hardwood component reaches maturity before tolerant softwood species. In this context, this study aims to explore the role of partial cutting as a secondary disturbance influencing species composition, stand structure and tree growth. Using three experimental trials set in place between 1999-2002, different approaches will be used to develop an understanding of the effect of partial harvesting on stand dynamics of the eastern boreal mixedwood. First, inventory data (diameter, basal area, height, recruitment and mortality) from two measurement periods will be used to examine post harvest stand structural responses relative to unharvested controls. Second, stem analysis will be used to examine radial, height and volume growth responses of residual trees after partial harvests. Third, the SORTIE model will be used to explore short- to long-term stand development. Analysis of reference (control) stands will provide insight into the dynamics of aspen-dominated stands during the canopy transition phase of stand development. Individual-based analysis of residual trees responses of aspen and white spruce in different crown classes will provide new quantitative information on growth response related to species ecology. Simulation of different partial harvesting scenarios to forecast stand development patterns will contribute to a greater understanding of the potential of these treatments as a 'natural disturbance emulator' in the context of forest ecosystem management.
Western Boreal Growth and Yield (WESBOGY) Association Long Term Study: Development and dynamics of young aspen-spruce mixedwood stands

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The Western Boreal Growth and Yield Association (WESBOGY) is a regional association of industrial, federal, provincial and university foresters and researchers interested in evaluating the dynamics of boreal forest development and the yield implications of silviculture practices. The four western provinces and the Northwest Territories are represented among the members. In 1992, WESBOGY began a long term study to evaluate the effects of aspen and spruce densities on the long-term dynamics of mixedwood stands. Eleven replicate installations of this study have been established in western Canada since that time. This poster describes the study design and presents results from recent analysis showing height, height increment, diameter and height/diameter ratio responses for spruce and aspen in the different treatments.

The Validation of the Mixedwood Growth Model (MGM)

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The Mixedwood Growth Model (MGM) is an individual tree, distance independent growth model developed at the University of Alberta for use in the boreal forest. The model has been developed to enable decision makers explore potential outcomes of a range of forestry practices. This poster presents the results of a validation that compared model predictions against plot data using 4 permanent sample plot datasets. The datasets represent juvenile managed and mature unmanaged stand conditions from Alberta and Saskatchewan. Residual plots and statistical tests (average mean bias, relative model bias and efficiency) show that the model validates well for both juvenile and mature stages of stand development for both pure and mixed species stands of aspen, spruce and lodgepole pine.
Impact of Seasonal Harvesting in the Northern Boreal Forest on Soil Physical Properties and Aspen Regeneration

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On a boreal mixedwood harvest project designed to determine optimum cutting strategies for mature aspen (Populus tremuloides Michx.) while protecting understory white spruce (Picea glauca (Moench) Voss), a study was superimposed to determine the effects of seasonal harvesting of aspen on soil bulk density, total porosity, aeration porosity, and regeneration and growth of aspen suckers. Harvesting occurred in September 1993 (fall-harvested) and February 1994 (winter-harvested) and subplots delineated across and along machine corridors were designated Centre, Track, and Side to represent areas between tire tracks, along tire tracks, and at the side of machine corridors, respectively. Post-harvest sampling was done annually 1994-2000 (except 1996), and a second harvest entry in fall 1998 and winter 1999 was followed by regeneration monitoring in 1999 and 2001. Compared with winter-harvested blocks, fall-harvested blocks increased significantly following harvest in bulk density (10-17 \%) and decreased significantly in total porosity (10-11 \%) and aeration porosity (17-30 \%). Track locations were most severely affected by harvesting as bulk density increased 24 \% by the fourth growing season after harvest, while total porosity and aeration porosity decreased 17 \% and 44 \%, respectively. Fall harvesting also caused density and height of aspen suckers to decline by 8 \% and 22 \%, respectively. Neither soil properties nor aspen regeneration was ameliorated by second-entry harvesting. Winter harvesting of aspen on fine textured soils of boreal forests was a superior forest management tool; soil properties and aspen regeneration were not compromised, as was the case with fall harvesting. This provides valuable information of harvesting impacts on fine-textured, non-frozen soils in Northern Alberta.
Do deciduous - coniferous mixtures mean better yield? Influence of deciduous encroachment in spruce plantations.

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Plantations are an important regeneration practice in the boreal mixedwood forest of eastern Canada. When conifer plantations are established, available light and nutrients allow the development of opportunist species including shrubs and intolerant hardwood species. These invasive species capture resources at the expense of planted trees and thus can reduce seedling growth. Conversely, in mature stands, it has been shown that the presence of deciduous species can have beneficial effects on spruce growth. However, the effect of hardwood presence at intermediate stages - between seedlings and mature trees - is poorly documented. The first objective of this study is to qualify and quantify the facilitative and competitive effects of opportunist species in 15 to 30 year-old black and white spruce plantations in the mixedwood forest of western Quebec. The study considers neighborhood density, distance, species and size effects on yield at the stand and tree scales. A competition analysis was performed on 378 target trees distributed over 126 plots where all individuals were mapped. The second objective is to verify the two following hypotheses: that the deciduous component 1) reduces the competitive pressure on soil resources by accelerating canopy closure, and (2) by its effect on soil physical properties, allows better access to water by conifers. The relationship between the presence of opportunist species, water stress of target trees and soil properties is thus explored.
Regional Models of Diameter as a Function of Individual Tree Attributes, Climate and Site Characteristics for Six Major Tree Species in Alberta, Canada

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Accurate measurements of diameter and height are of critical importance to forest managers and practitioners in the decision-making process, since these tree attributes allow the indirect estimation of stem volume, biomass, and site index. For instance, the estimation of stem diameter from height for individual trees plays a pivotal role in the development of reliable growth and yield curves and in the development of detailed forest inventories. We investigated the relationship of stem diameter to tree, site and stand characteristics for six major tree species (i.e., trembling aspen, white birch, balsam fir, lodgepole pine, black spruce, and white spruce) in Alberta (Canada) with data from Alberta Sustainable Resource Development Permanent Sample Plots. We developed models to estimate diameter at breast height using height, crown and stand attributes using non-linear mixed effects modeling techniques. Mixed effects models (with plot as subject) using height, crown area, and basal area of the larger trees explained on average 95% of the variation in diameter at breast height across the six species with a root mean square error of 2.0 cm (13.4% of mean diameter). Fixed effects models (without plot as subject) including the Natural Sub-Region (NSR) information explained on average 90% of the variation in diameter at breast height across the six species with a root mean square error equal to 2.8 cm (17.9% of mean diameter). Selected climate variables provided similar results to models with NSR information. The inclusion of nutrient regime and moisture regime did not significantly improve the predictive ability of these models. These models are a step forward in allowing the prediction of stem diameter at regional level using measurements of height and crown area provided by remote sensing.
Asymmetrical diameter-limit versus fixed spacing précommerciale thinning in aspen: initial treatment effects

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Although précommerciale thinning (PCT) in aspen stands is an uncommon practice in Quebec, the current standard of 1,100 evenly spaced stems ha\(^{-1}\) (2.5 -3.5m between stems) is generally applied. Because this standard prioritizes distance between stems, in many cases to the detriment of vigorous and relatively large-sized but proximal stems, we questioned whether individual tree and stand growth potential was negatively affected by this standard. Moreover, we were interested in creating mixed stands by planting white spruce within thinned 11 year-old aspen stems. In order to compare conventional, distance-based PCT and diameter-limit-based PCT, we established a randomized block design silvicultural trial with three blocks containing four treatments: conventional PCT (1,100 stems ha\(^{-1}\)), diameter-limit PCT 1,100 stems ha\(^{-1}\), diameter-limit PCT 2,200 stems ha\(^{-1}\) and unthinned controls. Thinning treatments were applied in the fall 2010 an early spring 2011 and spruce were planted in summer 2011. Prior to treatments, intensive forest inventories were conducted to generate stand tables for all experimental parcels and determine lower diameter cut-off limits to retain the 1,100 and 2,200 in the largest stem size classes in the DL-treatments. Because the trial was only established in 2011, this poster essentially describes the project and initial effects of the treatments on density, diameter and height of residual stems.
Validating the Mixedwood Growth Model (MGM) using Juvenile White Spruce PSP’s in the Saskatchewan Mixedwoods

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Juvenile forest growth can have long-standing implications to stand rotation length and landscape management decisions. Between 1992 and 1994, twenty-four permanent sample plots (PSP’s) were established in 3-12 year old white spruce (*Picea glauca*) plantations across the Prince Albert Forest Management Agreement of north-central Saskatchewan. In 2011, twelve of these PSP’s were re-measured. Using the 1992/1994 and 2011 PSP observations, juvenile white spruce growth was modeled using the Mixedwood Growth Model (MGM) and compared to the empirical growth observed between 1992 and 2011. In addition, each PSP was modeled through a hypothetical 120-year rotation using MGM, followed by a discussion of long-term growth outcomes.
Boreal mixedwood is a complex ecosystem representing a mosaic of stands varying in size and composition. Forest fire, which is also irregular in shape, size and severity, plays a key role in shaping this mosaic by initiating forest succession. Other disturbances such as insect outbreaks also strongly influence the dynamics of this ecosystem. Boreal forest succession is difficult to study because it spans several hundreds of years and can be affected by stochastic environmental conditions. The methods for understanding this temporal dynamics can be direct, thus allowing real-time study of the changes occurring in the forest (e.g. repeated observations in permanent plots), or indirect, by using successional stages of different ages (e.g. chronosequence). We studied the changes in forest canopy composition in boreal mixedwood of western Quebec with both direct and indirect methods. We sampled 439 plots in the forest mosaic in 1991 and revisited the same plots in 2009, allowing us to characterize the changes over nearly 20 years in seven areas forming a chronosequence of 249 years. We studied the dynamics at both the landscape (fire area) and the stand (plot) scale and tested the hypothesis that time since last fire is the main factor explaining the structure and composition of stands. We also evaluated the effect of a severe spruce budworm outbreak that affected balsam fir and white spruce just before the first sampling. The combination of the direct and indirect methods allowed us to assess the reliability of using the chronosequence to understand forest succession. Our results indicate that the time since last fire was the main factor explaining forest succession in the first 150 years after a fire, and that the occurrence of a spruce budworm outbreak can significantly alter the successional sequence in older forests. We also found that chronosequence was a reliable tool to understand the dynamics of forest canopy across the landscape in young forests, as well as for older forests when combined with a good knowledge of insect outbreak history. However, at the stand scale, direct methods performed better because there are multiple successional pathways.
Seasonal foliar nutrient variation in plantation white spruce growing in mixture with varying levels of trembling aspen competition

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Foliar nutrient concentrations were analyzed for even-aged, plantation white spruce (Picea glauca [Moench] Voss) growing with varying amounts of trembling aspen (Populus tremuloides Michx.) competition in northwestern Ontario. Species mixture was determined as the proportion of competition experienced by a subject tree from each species using Hegyi’s size-ratio, distance-dependant competition index. White spruce foliar concentrations and ratios of N, P, K, Ca, Mg and micronutrients were measured in current year needles throughout the 2010 growing season. Seasonal trends were evident in concentrations of N, P, K, and Ca, as well as in nutrient ratios (Ca/N, Mg/N, Mn/N, and Zn/N). Significantly lower (p < 0.05) foliar P, K, and P/N and higher Ca, Ca/N, Mn/N, and Zn/N were observed in white spruce foliage from trees in spruce-dominated stands compared to those growing in mixtures with aspen. The presence of aspen appeared to influence the amount and duration of nutrient uptake, indicating the importance of differentiating between mixed- and mono-cultures for foliar nutrient research in plantation white spruce.
Investigating productivity and foliar nutrient status in second growth white spruce (*Picea glauca*) and trembling aspen (*Populus tremuloides*).

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This study investigated mixedwood productivity, white spruce and trembling aspen growth rates and white spruce nutrient status along a range in density and mixture. Growth rates, in the form of periodic basal area increment (PBAI), were measured from the cores of 39 white spruce trees and 44 trembling aspen. Core tree-rings were measured using WinDENDRO software. The 39 sample spruce trees were analyzed for several foliar macro- and micro-nutrient concentrations. Foliar nutrient contents were estimated using an allometric equation for foliar biomass of plantation grown white spruce. Nutrient use efficiencies were determined as the relative amount of nutrient invested per unit growth. PBAIs were scaled to compare site productivity. The relationships between spruce and aspen growth rates, spruce nutrient status and productivity with mixture proportion and density were analyzed as response surface designs. Mixture proportion and density adequately predicted aspen PBAI (p =0.02), white spruce foliar concentrations of P, K and Ca/N (p =0.053, 0.060 and 0.031, respectively), as well as mixedwood productivity (p =0.001). Results suggest that 20 year old plantation spruce-aspen mixedwoods experience decreased intra-specific competition than do monocultures of either species. A facilitative relationship is expected to exist between these species where nutrients are limiting growth.
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