The Role of Broadleaf Trees: Impacts of Managing Boreal and Sub-boreal Mixedwood Forests in British Columbia

Introduction

Within the boreal and sub-boreal forests of northern British Columbia (B.C.) large areas of broadleaves occur naturally in mixture with conifers or as pure stands. Many conifer plantations contain significant numbers of naturally regenerating trembling aspen, birch, and cottonwood. Broadleaves have historically been undervalued and considered an impediment to conifer establishment and growth, as reflected in the free-growing guidebooks that suggest limits to the presence of broadleaf trees in regenerating stands (BC MOF 2000; BC MFLNRO 2013). Legislation and policy have evolved to promote practices that minimize broadleaf impact and optimize conifer stand growth and yield (GY) with the goal of supporting a sustainable timber supply (Figure 1).

FIGURE 1 In British Columbia mixtures of broadleaf trees and conifers are a natural part of boreal and sub-boreal landscapes but historic forest management practices have favoured pure conifer stands.
Although broadleaves certainly can have antagonistic effects on conifer growth and survival and currently have lower value, they also contribute positive influences and attributes (St. Clair et al. 2013). They provide various ecological, social, and non-timber values; have significant value in shaping forest ecology, stand structure, and function; and exert a strong influence on forest diversity and resilience.

Broadleaf trees also offer quality timber and a unique opportunity to diversify the forest industry. Broadleaves currently are harvested on a limited basis for use in plywood, oriented strand board (OSB), pulp, and furniture grade lumber.

In 2000 and 2008, the Ministry of Forests and Range acknowledged the potential benefits of managing broadleaves and indicated interest in using broadleaves to satisfy silviculture obligations (Pedersen 2000; Sheldan and Snetsinger 2008). Since then, there has been little mainstream acceptance of incorporating broadleaves into timber supply planning. Attempts to actively manage for broadleaves and broadleaf–conifer mixedwoods have introduced a conundrum of confounding policy issues, timber supply concerns, and uncertain silviculture and GY outcomes. However, the recent economic and forest health challenges associated with the long-term timber supply impact of the mountain pine beetle epidemic have seen accelerated timber supply mitigation efforts and created the impetus for policy changes designed to enhance short- and mid-term fibre supply (BC MFLNRO 2012). Interest in broadleaves and broadleaf–conifer mixedwoods continues to increase as alternative sources of fibre are sought. Formal integration of broadleaf and mixedwood silviculture into the presently conifer-centric forest management is needed to facilitate successful market integration and industry diversification.

The challenge of integration has many facets. However, there is an underlying need to clearly define stand- and forest-level objectives across multiple resources and social values. Current attempts at defining the impacts of broadleaves on conifers and timber supply expectations represent an evolution and acknowledgement of the significant challenges that still exist within the context of timber supply, forest policy, and forest management.

Clearly, greater awareness is needed of broadleaf species timber values as well as the contributions to forest ecology, forest resilience, and forest health (Figure 2). In 2012, a comprehensive literature review documented the present state of knowledge relating to the value and impact of including broadleaf trees in managed boreal and sub-boreal stands in British Columbia (Roach 2013). Timber and non-timber values were compared between “pure” conifer stands and “mixed” conifer–broadleaf forests. Mixedwood stands were defined as having two or more species occurring together with no one species comprising more than 70–80% of the total basal area. The literature review focused on:

- both GY and non-timber forest values;
- white spruce–trembling aspen and lodgepole pine–trembling aspen mixtures;
- Boreal White and Black Spruce (BWBS) and Sub-Boreal Spruce (SBS) biogeoclimatic zones; and published and peer-reviewed papers.

Information on other conifer–broadleaf combinations that occur in boreal and sub-boreal British Columbia and northern Alberta was included where information about spruce–aspen and lodgepole pine–aspen mixtures was limited. The other species included balsam poplar, paper birch, black spruce, and jack pine. Research results from boreal and sub-boreal areas across Canada that are similar to British Columbia’s BWBS and SBS zones were included where local data were lacking or limited.

The key findings and knowledge gaps identified in the literature review highlight the need for enhanced research and monitoring programs to

**FIGURE 2** Research and monitoring are critically needed to understand the consequences of different management scenarios for boreal and sub-boreal forests.
quantify and document values, costs, uncertainty, and risk inherent in considering the future condition of boreal and sub-boreal forests within the context of a changing climate, increasing natural resource demands and expectations of sustainable ecosystem function.

**Key Findings**

**Free-growing**
Including broadleaf trees in conifer stands makes it difficult to meet the conifer to brush ratios that are found in British Columbia’s current free-growing requirements. Mounting evidence indicates that greater broadleaf presence than is currently permitted in the free-growing guidelines may still result in acceptable performance of conifer trees on some sites.

**Economics**
Chemical treatments are currently considered more cost-effective in the long-term than other aspen removal treatments because treatment application is cheaper and/or conifer growth responses are greater. Based on current markets, planting conifers and removing broadleaves will result in higher long-term financial returns than retaining broadleaves because conifer wood is more valuable than broadleaf wood. However, the cost effectiveness of different treatments depends on future value and demand for broadleaves compared to conifers, which are largely unknown (Figure 3).

**Growth and yield**
Table 1 summarizes the influence of broadleaf trees on conifer productivity.

The Mixedwood Growth Model (Bokalo et al. 2013) consistently projects reduced spruce volume at rotation when broadleaves are included in stands. Including broadleaves in conifer stands amounts to “trading” some of the conifer volume for broadleaf volume, but results in similar or higher total (conifer plus broadleaf) volume than in pure stands (Figure 4).

Mature aspen stands with a spruce component tend to have greater total productivity than mature pure aspen stands, which again suggests greater total productivity of mixtures than pure stands.
**Table 1 Potential conifer stand productivity impacts of retaining broadleaves in the BWBS and SBS zones**

<table>
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<tr>
<th>Broadleaf effect</th>
<th>Impact on stand</th>
<th>Knowledge gap</th>
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| Interspecific resource competition | • Reduced growing space, light, moisture, and nutrients available for conifers  
• Competition usually considered to be primarily for light but moisture availability may also be important  
• May be less understorey brush competition due to early broadleaf dominance, higher regeneration densities, and lower understorey light levels  
• Stand self-thinning, self-pruning and smaller branch size development can be expected on all shade-intolerant tree species in response to higher densities and growing space competition  
• Reduced conifer diameter due to reduced crown and branch size (density and species dependent)  
• Reduced conifer height growth (site and species dependent)  
• Increased pine mortality (site dependent)  
• Increased conifer stem damage | • Lacking information on moisture and nutrient competition between conifers and broadleaf trees  
• Need information on spatial and temporal interactions between conifer and broadleaf species  
• Broadleaf threshold densities that will ensure site objectives will be met need to be determined |
| Faster height growth of aspen than white spruce and pine (most BWBS and SBS sites) | • Broadleaves have a competitive advantage in many natural mixed stands due to their faster initial height growth, resulting in multi-layered stands  
• In general, as broadleaves mature height growth declines and after many decades surviving conifers “catch up” to broadleaves  
• Conifer GY may be reduced in mixed stands compared to pure conifer stands, but total (all species) yield may be the same or higher in mixed stands  
• Conifer diameter growth is affected more than height growth  
• Conifer mortality may occur depending on species shade tolerance and broadleaf density | • Need to establish, and monitor new and existing permanent sample plots to provide long-term data on GY of mixed stands resulting from underplanting white spruce beneath aspen, planting spruce into partial cuts/shelterwoods, and thinning conifer/aspen stands  
• Tree productivity data are needed for a range of species proportions, stand densities, stand structures, climatic areas, and sites. Priorities must be set because there are too many combinations. |
| Height growth of juvenile aspen less than that of lodgepole pine (some SBS sites) | • Conifers may have a competitive advantage on drier sites or sites where site preparation or brushing treatments may have reduced aspen vigor (crown and leaf size)  
• Broadleaves may experience reduced growth rates, vigor, and/or mortality when conifers overtop them and conifer site occupancy occurs rapidly  
• Lodgepole pine stands may not suffer reduced GY if most pine remain taller than the aspen | • Need to determine sites/situations where juvenile conifer growth is expected to exceed broadleaf growth |
| Environmental biophysics | • Broadleaves such as aspen may help protect white spruce seedlings from frost and weevil damage  
• Shading from aspen may reduce spruce–Calamagrostis canadensis competition  
• Hare damage tends to be higher under aspen canopies than in clearcuts  
• Understorey light levels and summer daytime air and soil temperatures tend to be reduced by aspen cover | • Need to determine threshold aspen levels for reduction of frost damage, weevil damage, and understorey vegetation competition |
### Table 2: Non-stand productivity impacts associated with including broadleaf trees within conifer-dominated stands and landscapes

<table>
<thead>
<tr>
<th>Element</th>
<th>Benefits</th>
<th>Disadvantages or knowledge gap</th>
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<tbody>
<tr>
<td><strong>Economics</strong></td>
<td>• Brushing costs may be reduced or eliminated</td>
<td>• Harvesting is considered more complex/expensive in mixed stands</td>
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<td>• Silviculture costs may be reduced through improved white spruce seedling survival (protection from frost and reduced <em>Calamagrostis</em> grass competition through shading)</td>
<td>• Potential trade-off of conifer volume for broadleaf volume. At present in British Columbia broadleaf trees have lower value than conifers.</td>
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<td>• Increased forest industry product diversification may create new market and product opportunities, add value and jobs to the sector, as well as create indirect socio-economic opportunities</td>
<td>• May increase planting costs due to increased conifer seedling animal damage or mortality by providing cover for hares or other mammals</td>
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<td>• Inaccurate and imprecise broadleaf inventories may be a concern in sustaining hardwood product supply as well as market integration of new products. A lack of awareness and sensitivity towards hardwood management and economic opportunities is a challenge.</td>
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<td><strong>Wood quality</strong></td>
<td>• Wood quality potentially increased in both broadleaves and conifers where mixedwood canopy conditions promote less taper and smaller, fewer branches that self-prune sooner</td>
<td>• Lumber from aspen/cottonwood trees is considered less desirable than from conifers</td>
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<td>• Markets already exist for broadleaf wood products. Aspen /cottonwood are currently used for oriented strand board (osb), laminated veneer lumber (lvl), plywood, construction lumber, appearance grade products (matches, chopsticks, etc.). Birch is used for high value lumber (appearance and millworking grades), veneer, plywood, and pulpwood.</td>
<td>• Broadleaf lumber kiln drying schedules are significantly different than that for conifer lumber</td>
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<td>• Limited or dispersed volumes of quality birch – due to past management and other factors – may limit the amount of economically useable material needed for local processing facilities</td>
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<td><strong>Carbon storage</strong></td>
<td>• Increased carbon storage</td>
<td>• Short-lived tree species compared to conifers</td>
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<td><strong>Biological and genetic diversity</strong></td>
<td>• Vegetation community diversity may be required to maintain historic ecological site conditions and / or rare plant associations</td>
<td>• Vegetation species specific to mixed boreal and sub-boreal stands have not been identified</td>
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<td>• Highest plant species diversity usually found in broadleaf stands and sometimes in mixed stands</td>
<td>• Desirability of increasing the seral deciduous and mixed stand components at the landscape level needs careful consideration and must be evaluated at the landscape level</td>
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<td>• Mixed stands typically include species found in both pure broadleaf and pure conifer stands</td>
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<td></td>
<td>• Greater avian species diversity in aspen–conifer mixedwoods than in pure stands. A few bird species are mixed-stand specialists</td>
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<td><strong>Wildlife habitat</strong></td>
<td>• Large aspen trees with decay provide essential habitat for cavity nesters</td>
<td>• Retention of mature broadleaf stems for maintaining a supply of wildlife trees may be difficult to integrate with other site management goals</td>
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<td>• Ungulate browse provided by juvenile broadleaf trees</td>
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<td><strong>Forest health</strong></td>
<td>• Reduced frost damage and weevil attack under aspen canopies</td>
<td>• Increased hare damage under aspen canopies</td>
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<td></td>
<td>• Reduced conifer root disease levels in mixed stands</td>
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<td><strong>Soil nutrients and rooting</strong></td>
<td>• Higher nutrient availability</td>
<td>• Some research suggests aspen does not improve nutrient availability in the BWBS zone</td>
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<td></td>
<td>• More diverse ectomycorrhizal fungi</td>
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<td></td>
<td>• Soil resources exploited more effectively</td>
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<td>• Higher fine root productivity</td>
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Growth and survival – white spruce/aspen mixtures

Even-aged mixtures
Removing aspen from even-aged spruce–aspen mixtures usually results in increased diameter growth and decreased height to diameter ratio of spruce (Figure 5). The volumes of spruce 5–10 years after complete aspen removal tends to be double that of spruce in untreated mixed stands. Mortality of planted spruce within regenerating aspen tends to be low.

Uneven-aged mixtures
Underplanted white spruce usually has reduced diameter and height growth compared to spruce grown in the open but its survival is typically good provided aspen canopies are not too dense.

Complete removal of an established aspen canopy typically results in substantially increased height, diameter, and therefore volume growth of white spruce. Spruce growth responses are lower when aspen is partially removed.

Growth and survival – lodgepole pine/aspen mixtures
Data from the Sub-Boreal Spruce zone (SBSdw1) indicate that survival of lodgepole pine declines significantly with increasing density of aspen taller than the pine. The threshold for 80% survival of pine has been estimated at 7000 stems per hectare of tall aspen (Newsome 2009).

The height growth of lodgepole pine in the SBS zone is not consistently improved by reducing aspen density, but some studies show height growth increases when tall aspen density is reduced to less than 4000–5000 stems per hectare. Some SBS studies have shown that diameter growth of juvenile lodgepole pine starts to decrease at tall aspen densities of 1000–2000 stems per hectare, but in other studies this density of aspen had no effect on diameter growth.

Thresholds for lodgepole pine and white spruce performance are specific to the site and stand age.

Non-growth and yield values
Table 2 summarizes the influence of broadleaf trees on non-gy values.

Knowledge Gaps
A literature review (Roach 2013) identified that quantitative knowledge regarding the inclusion of broadleaf trees in managed stands in the BWBS and SBS zones in British Columbia is limited and critically needed, especially for the long term. It is difficult to predict outcomes of various management strategies without this knowledge.

Information needs include:
• An economic analysis of alternative silviculture treatments for boreal and sub-boreal mixedwoods.
• A review of the broadleaf wood product economics (especially aspen, cottonwood, and birch), based on international and local demand and experience (Figure 6).
• The impact of a range of broadleaf management options on long-term timber supply.
• Long-term data describing the gy of pure versus mixed conifer–broadleaf stands of varying species proportions in the BWBS and SBS zones (e.g., repeated measurements of mixedwood permanent sample plots and research installations.

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| Fire protection | • Aspen less flammable than conifers  
• Aspen stands valuable as firebreaks | • Mixed aspen–conifer stands less effective than pure aspen for fire protection |
| Cultural values | • Important First Nations cultural uses  
• Sap (birch) and other non-timber products can be extracted from broadleaves and marketed  
• Increased visual diversity and aesthetic qualities | |

Table 2 Continued

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FIGURE 5 A mixedwood management thinning of aspen to promote the growth of planted white spruce and trembling aspen. Density of the naturally regenerated aspen was reduced from 29 000 to 1 200 stems per hectare (Kabzems et al. 2011).
stands. Some research findings in the BWBS zone conflict with the general assumption that growing conifers with aspen produces nutritional benefits.

- Biodiversity associated with the changing tree species composition of mixedwood stands. Analysis of plant community diversity at the stand and landscape levels within the SBS broadleaf and mixed stands.
- Analysis of habitat requirements and diversity at the stand and landscape levels of organization for bird and mammal populations. How does mammal use within broadleaf–conifer stands compared to pure conifer or pure broadleaf stands in boreal or sub-boreal forests.
- Information on how to remedy negative effects of avian habitat loss and fragmentation at the landscape scale when broadleaf trees are removed.
- Information on vegetation and wildlife communities found within mixed and pure stands to better understand the influence of over-storey trees, nutrient cycling, and long-term competition.
- A comprehensive review of the cultural importance of mixed boreal and sub-boreal stands in British Columbia.

Summary

Retaining aspen or other broadleaf trees in managed BWBS and SBS stands in northern and central British Columbia has both advantages and disadvantages. Broadleaf competition tends to reduce conifer volume but not at low densities. However, mixed stands may have similar or higher total volume (conifer plus broadleaf) than pure stands. Economic considerations, such as silviculture liabilities and treatment costs, revenues of conifer versus broadleaf timber, relative wood quality and value, and timber supply and markets for conifer and broadleaf products, will continue to influence forestry management decisions. However, key knowledge gaps need to be addressed to reduce the uncertainty around defining broadleaf and mixedwood management (Figure 7). More information is needed to help define broadleaf retention thresholds at the stand, forest, and landscape levels within the present conifer-centric forest management.

Further investigation into the ecological, economic, and social costs of managing for “pure” stands versus mixed conifer–broadleaf stands needs to be made a priority. A greater awareness of the issues surrounding broadleaf and mixedwood silviculture is an essential element of informed treatment and land management decisions.
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