A DETAILED LITERATURE REVIEW OF
RED ALDER MANAGEMENT IN MIXEDWOOD STANDS

by

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Abstract

This literature review is a synthesis of recent publications and developments regarding the growing acceptance and potential of *Alnus rubra* (Bong) commonly called red alder. The project summarized some of the concerns and benefits of including red alder in coastal forest mixedwood management strategies. Some of the concerns include overtopping of conifers and competition for light. Some benefits include increases to site productivity, biodiversity, forest health and diversification of the coastal forest industry. It also examined past and current industry and government policies towards alder in mixedwood management and recent changes in some of these policies including the just released "Hardwood Management in the Coast Forest Region" policy paper.

There is now recognition of the importance of alder management and there is a framework in place for patch mixedwood management in coastal BC. But before intimate mixedwood strategies are accepted and used operationally, further research and trials are required. There needs to be a better understanding of both the competetitive and beneficial effects of red alder in mixture with conifers for complex forests to in order to assist forest managers in making sustainable management decisions.

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3.0 Introduction

Historically, the forest industry in Coastal British Columbia was centered around the harvest of softwood, beginning with the preferred conifer, old growth Douglas-fir (*Pseudotsuga menziesii* var.*menziesii*), and progressing to the harvest of other species in natural stands to the present day focus on plantation management. Hardwoods were generally considered to be nuisance wood and were often left to rot after conifer harvest and also removed from new conifer plantations through brushing treatments (both mechanical and chemical). Most research was directed at silviculture strategies aimed at increasing the growth of conifer crop trees which often included controlling hardwood competition.

For the purpose of this essay, the term ‘hardwood’ will be used synonymously with *Alnus rubra* (Bong), commonly know as red alder. For a number of reasons, a shift occurred in the mid twentieth century towards research into the biology of red alder, with an alder growth and yield trial initiated at the Cowichan Lake Research Station in 1935, followed by the establishment of a thinning plot at the same station (Warrack 1949). Many early trials took place to better understand red alder in order to control it.

Initially there was no demand for red alder from a marketing point of view. As well there was and continues to be a bias within the forest industry and government agencies against including and promoting red alder for crop trees. This occurred for a variety of reasons including a historical bias towards conifer management in the forest industry, initial scarcity of research on hardwood management and marketing, and government policies which focused only on conifer management.

Even when industry suggested changes in these policies, government was sometime reluctant to collaborate (Hughes, 2002).

Due to the diligence of researchers there is currently an abundance of research available on red alder prompting one researcher to contend that, in relation to its nitrogen fixing abilities, it is the most thoroughly investigated species prior to its implementation in operational forestry (Tarrant 1994). Because of this research it is now recognized that red alder provides important biological benefits, cultural benefits, and is gaining a niche in the wood sales market.

One of the leading organizations in red alder studies in the Pacific Northwest is the Hardwood Silviculture Cooperative (HSC). The HSC was started in 1988 at Oregon State University and now has members from industry, government and academic sectors from the United States and Canada. The main goal of the HSC is to provide forest managers with an understanding of the issues surrounding red alder management. As of 2005-2006 the HSC had the most extensive red alder growth data base in existence. It is now a multi-faceted research and education program focused on the silviculture of red alder and mixes of red alder and conifer in the Pacific Northwest. The main priority of the HSC is to understand the response of red alder to intensive management. The HSC data-set on growth of managed stands aims to make red alder one of the better-understood forest trees of the Pacific Northwest. The HSC red alder study design includes thirty-six study installations from Coos Bay, Oregon to Vancouver Island, British Columbia. These study installations are divided into 3 types: 4 thinning studies in natural stands; 7 replacement studies of red alder and Douglas-fir mixes; and 26 variable density plantations with thinning and pruning treatments. In 2005, fourteen of the twenty six plantations were at least 12 years old. These installation sites are the basis of many subsequent studies and reports which are also investigating mixedwood stand dynamics.

These studies plus other from industry have recently led to policy changes allowing for improved management of mixed conifer and deciduous stands. This is a difficult area of study as mixedwood management in forestry is a relatively new and complex concept and difficult to model. However, there is a gradual acceptance of the idea that there is a place for silviculture management strategies which include mixes of red alder and conifer.

The main focus of this essay is to review some of the literature relating to different mixedwood strategies as they affect the Pacific Northwest and especially coastal British Columbia. The following key questions related to this topic are of interest to researchers, industry and regulating agencies. Does red alder contribute to forest health, tree growth and timber production when grown in mixedwood stands? What are the optimal target densities for pure and mixed wood stands? What are the current policy and management options available to forest practitioners for mixedwood management?

4.0 Benefits of Red Alder in Mixedwood Management

4.1 Site Productivity

A growing number of studies point to some of the advantages of growing alder with conifers, showing that red alder can contribute to the long term productivity of a site. Early studies recognized that red alder adds nitrogen to the soil through a symbiotic association with *actinomycetes* bacteria (Frankia spp.). The nitrogen is used by red alder trees then transferred to the soil by root decay and leaf fall thereby increasing soil fertility. Alder can assimilate up to 200 kilograms of nitrogen per hectare per year (Binkley et al. 1994). It is known that many coastal sites have low nitrogen levels. On nitrogen poor sites, mixtures of red alder and conifer may result in greater whole stand productivity than in pure conifer sites (Binkley, 2003. Courtin et al. 2002). Interesting results from a seven decade study looking at the possible effects of nitrogen on development in pure stands of conifers compared to mixed stands, support the idea that including alder in conifer stands on lower productivity sites should increase the yield of conifers late in rotation (Binkley, 2003). On the other hand there is evidence to show that inclusion of alders in conifer stands on nitrogen rich soils will probably lower both total stand growth and conifer yield (Binkley and Greene 1983, Binkley 2003). These findings suggest that in relation to nitrogen production, alder is best suited for low to medium rich sites.

One of the main concerns with alder/conifer mixedwood management has been the detrimental effect of alder trees hindering light from reaching understory conifers. For example, red alder was shown to hinder the growth of conifers by restricting light transmittance (Comeau 1996). Recently, Lavery *et al.* (2003) in their study of the influence of red alder patches on light, litterfall, and soil nutrients in adjacent conifer stands found that the alder cast shade for only a short distance into adjacent openings. They also found that although there was some variation attributable to stand height, light reached levels considered to be acceptable for Douglas-fir growth within 6 m of the alder stand edge. The competitive effects of alder shading adjacent conifer stands were found to be counterbalanced by the increased nitrogen availability from the fixation of atmospheric nitrogen. As well, they found that alder litterfall extended 8-18m into adjacent conifer stands. Leaf litterfall has been suggested as the primary mechanism for fixed nitrogen to be transferred into the surrounding soils (Bormann et al.1994). As well, conifer seedlings adjacent to alder patches had increased nitrogen content, suggesting that the enhancement of nutrient supply under alder may extend into the next generation of trees (Lavery et al. 2003). Other findings from this study were that the benefits of alder's presence on soil fertility are detectable sooner on poor sites and may be undetectable on very rich sites.

Ongoing trials to study the effects of red alder on stand dynamics and nitrogen availability are being undertaken by the B.C. Ministry of Forests in collaboration with the HSC. A recent report on the management of complex coastal mixedwoods in BC for productivity and free-growing utilizes mixed alder-conifer experiments to study the effects of red alder on conifers in the 11 year free growing window (Thomas et al. 2006). This study looked at four sites, Gough Creek, East Wilson, Holt and Waterloo. At each site one of 5 different densities of red alder (0, 50, 100, 200, and 400 stems per hectare (sph)) was applied. Measures of alder competition and conifer growth including alder basal area, alder height, proximity, alder crown area, light levels and others, were evaluated (Thomas, 2006). Results of this study indicate that Douglas-fir height growth is not adversely affected by alder densities up to 400sph. At two of the sites Douglas-fir height growth improved with the presence of red alder, probably due to the benefits of red alder increasing the available nitrogen. The average height growth of western red cedar (*Thuja plicata*) does not appear to be affected by the different densities of red alder (Thomas, 2006). One of the main findings of this study is that on some sites it is acceptable and desirable to have an alder conifer mixture with alder densities up to 400sph.

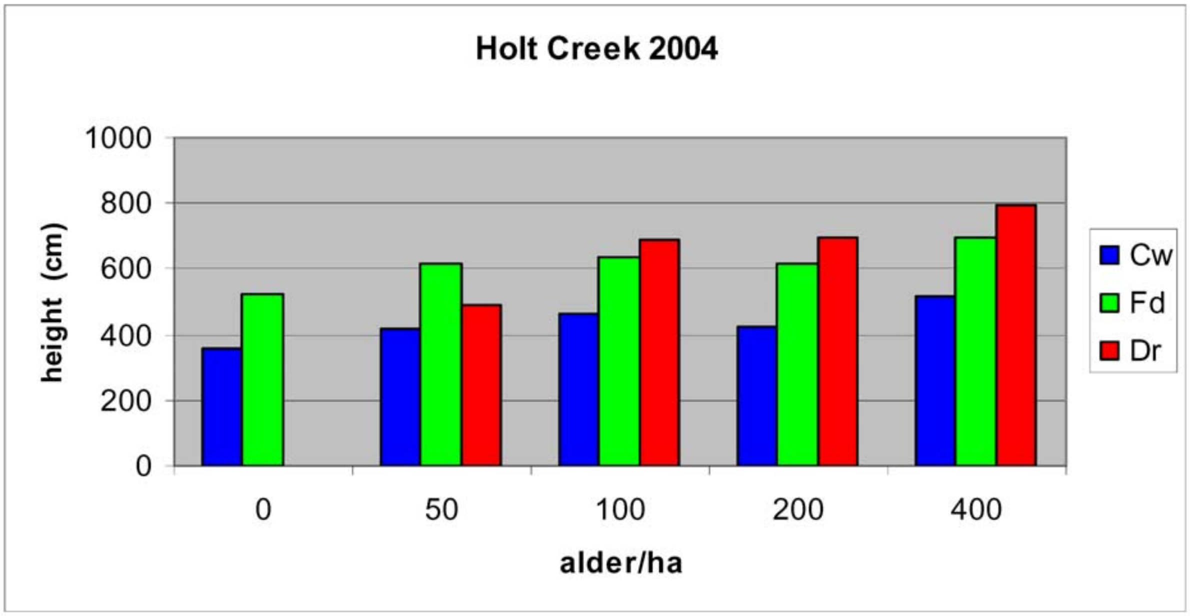

Figure 1. Average height of the three tree species at Holt Creek (Western redcedar = Cw; Douglas-fir =Fd; Red alder = Dr). (Thomas et al. 2006)

In summary, while alder competes with conifers for light, it also enhances conifer growth by increasing the amount of nitrogen available in soils, the challenge for management is to strike a balance between these two important factors.

4.2 Biodiversity and Forest Health

Biodiversity

Red alder can improve both stand level and landscape level biodiversity in coastal forests. Dense, uniform, even-aged stands of conifers that develop after clear cutting have many negative consequences for wildlife and fish. Forest canopies often close over after 25-35 years, followed by nearly complete elimination of understudy vegetation lasting an estimated 100 years or more. Aquatic and riparian productivity is also affected (Deal and Wipfli 2004). Density of red alder in headwaters influences vertebrate and detritus subsidies to downstream habitats (Wipfli and Musslewhite (2004). Based on their data, Wipfli and Musslewhite predict that headwater streams with more riparian alder will provide more invertebrates and support more downstream fish biomass than those basins with little or no riparian alder.

In mixed forests the alder start to die off after 35 years when they are overtopped by conifers. The space left by the dead alder allows more light to penetrate the forest floor. This in turn allows the growth of understory and invasion of new trees (Deal and Wipfli 2004). It has been suggested that this early death of alder accelerates that transition to mature forest structure. As well alder provides a supply of woody debris for streams and nitrogen and organic matter for decomposers and invertebrates.

Regarding mixedwood forests, recent studies have observed that including red alder with conifers may improve habitat and food for deer and other wildlife thereby offsetting some of the negative consequences of clearcutting. Furthermore, inclusion of red alder did not significantly affect the production of the largest trees which were found across a wide range of alder-conifer mixtures (Deal, Hennon, et al. 2004).

In summary, it is suggested that younger forests of mixed alder and conifer provide more heterogeneous structures and significantly higher understory biomass than pure conifer forests. Research has shown that red alder increases diversity and abundance of understory plants and provides forage for deer and small mammals. This diversity helps maintain complex stand structures that are an essential component of the forest ecosystem (Deal 2007), and may increase the overall resilience of the forest (Buss and Brown, 2008)

Forest Health

Research is ongoing into increased forest health associated with red alder and conifer mixes. Root diseases are estimated to affect approximately 10% of Douglas-fir stands in the Pacific North West with estimated losses of 4.4 million cubic metres. Infected areas may remain a hazard to new Douglas-fir plantations for as long as 100 years. (Hibbs and Bluhm 2006).

On the coast, the most prevalent root disease is *Phellinus weirii,* commonly called laminated root rot. This disease spreads by root to root contact or via fungal hyphae. This pathogen can reduce the productivity and harvestable yield of managed stands by 40-70% through mortality, growth reduction, and butt rot. Infected trees are more susceptible to windthrow and insect damage. In B.C. the annual wood volume loss to laminated root rot is estimated at 1.4 million cubic metres (Sturrock et al. 2006). To get rid of the inoculum, infected trees and stumps are often removed mechanically which is very expensive and can lead to problems with erosion and/or site disturbance. Another strategy is to plant non susceptible species (conifer or deciduous) on the infected sites. Research indicates that broadleaf tree species are immune to laminated root rot, and planting alder may reduce the disease's effect on Douglas-fir. To improve stocking levels in areas with scattered dead and dying trees, the use of tolerant species such as alder may prove beneficial (Sturrock et al. 2006).

Early results of mixed planting showed no significant reduction in mortality of *P.weirii* susceptible species (Wallis 1976) however, alder does function as a productive occupier of the site by keeping susceptible species out and producing fiber, cover, and site enhancement while *P.weirii* dies out. Besides its resistance to pathogens such as *P. weirii,* red alder can have a dramatic influence on community soil level microbial function, even in an ecosystem high in nitrogen resulting in strong differences between conifer soils and soils with alder present (Binkley et al. 1992, Cole et al. 1995). Further research will be needed to clarify the best management strategies to take advantage of alder's tolerance to this pathogen when considering mixedwood silviculture.

4.3 Diversification of the coastal forest industry

From a market point of view, broadleaf harvest makes up a small percentage of total harvest for coastal B.C. In the past ten years in which data is available, on average broadleaf harvest accounted for only 2% of the total harvest. Of this 2%, 69% was from alder, 10% was from bigleaf maple, 19% was from black cottonwood/hybrid poplar and 2% was from paper Birch (Buss and Brown, 2008).

The price of red alder logs used for sawn-wood products has increased over the past 10 years in B.C. and in the Pacific Northwest states, sometimes exceeding the value of second growth Douglas-fir. Harvests levels vary from year to year but do not appear to have increased consistently since 1994 (Buss and Brown, 2008).

There appears to be a growing niche for alder which could both fill a demand for non- conifer timber products, and ensure a diverse supply of wood for changing markets in the future. Other than major global economic downturns, red alder markets have tended to follow a different cyclical pattern than the commodity driven conifer market. The forest industry estimates are that hardwood logging and milling operations generate economic spin-offs of $60 million to the BC coastal economy (Coast Forest Action Plan, 2007).

5.0 Progression of Policy Changes regarding Alder Management in BC

5.1 North West Hardwood's Experiences and Examples

The Ministry of Forests (MOF) first awarded hardwood forest licences in 1996 to Coast Mountain Hardwoods. Five non-replaceable licences were awarded within the Coastal Regions Timber Supply Areas (TSA) to facilitate harvesting of red alder and to better secure logs supply to the Delta sawmill. Over the years, the company name has changed to North West Hardwoods (owned by Weyerhaeuser) and then to Weyerhaeuser Hardwoods and Industrial Products. For this report North West Hardwoods (NWH) will be used to refer to all of these companies.

Since the awarding of the licences in 1996, NWH has expressed concerns over the long-term red alder supply and the limited number of areas within the Vancouver Forest Region being approved for red alder management (MOF letter, 1997, not cited). The MOF responded by completing a report entitled “Red Alder Management within the Vancouver Forest Region” from which red alder management trials were allowed on up to 100ha a year. NWH initiated operational trials in 1998 and by 2005 had established approx 650ha of alder plantations. In 2002, NWH proposed a “Weyerhaeuser Alder Management Strategy” to the Sunshine Coast Forest District. This proposed strategy was refined numerous times and was finally approved in 2005 for all of Weyerhaeuser’s BC coastal operations. Initially, the MOF only approved the short and medium rotation plantation management regimes with the licensee taking responsibility for the associated spacing costs. Plantation management with active density management treatment was proposed to facilitate short rotations designed to address the predicted mid term timber supply shortfall.

Weyerhaeuser’s proposed mixedwood management strategy was allowed on a limited trial basis only. This mixedwood strategy proposed an allowance for a component of naturally occurring red alder in specific situations and on appropriate sites. The Weyerhaeuser proposal maintains that managing for alder crop trees that are growing as small clumps or pockets within a conifer stand can add overall value to the stand. These clumps or pockets are often naturally-regenerated alder areas where conifer seedlings did not survive. Some examples include: brush pockets along riparian areas, heavily browsed areas, or heavily disturbed sites where alder has dominated (Hughes, 2005). Managing for these alder clumps in these situations has many benefits. Silvicultural costs for fill planting conifers along with any brushing treatments are reduced or eliminated. Stand level biodiversity is increased and adjacent conifers can benefit from increased nitrogen availability. The Weyerhaeuser mixedwood approach also included allowing low levels (100sph) of red alder evenly spaced in conifer stands. The fact that a large proportion of the alder harvested in Washington State is from conifer stands containing an alder component (Hughes, 2005) supports mixedwood management regimes. Eventually, components of the Weyerhaeuser Alder Management Plan were incorporated into NWH's and other licencees Forest Stewardship Plans with associated red alder stocking standards.

NWH Example of Mixedwood Management

In 2008, a portion of a Powell River NWH cutblock was spaced as a mixedwood stand, with both red alder and Douglas-fir as preferred species. Alder heights at the time were approximately 10m. Spacers were directed to only select red alder as a crop tree where it was growing in patches that were: greater than 10m in diameter, contained appropriate densities, and contained alder trees with good form and small branch size. Where these patches existed, spacing crews were directed to bring the density down to 1000sph, by brushing the least desirable alder trees (quite often the red alder trees growing around the edges of the patch). Conifer trees growing within these alder patches were not brushed.

Areas without appropriate alder patches were promoted as conifer areas, and all red alder growing within 2m of conifer crop trees were mechanically brushed (Hughes Conversation, 2009, not cited).

5.2 Coastal BC policy changes around red alder management

Both industry bias and government policy surrounding red alder management in Coastal BC has changed drastically over the years. Initially red alder was treated as a weed species and actively killed either mechanically or through chemical methods (including broadcast aerial treatments).

When the "Establishment to Free Growing Guidebooks" was published in 1995, the MOF decided to delete broadleaf species due to a lack of data. Between 1995 and 2000, the deficiency in data was addressed and led to the revised (May 2000) "Establishment to Free Growing Guidebooks" reintroducing broadleaf species back into the species tables (MOF Letter, 2000). Unfortunately, even with the inclusion of alder in the regional stocking standards, Forest Districts did not allow any red alder planting as no strategies were in place as of 2002.

The "Coast Forest Action Plan' released in October of 2007 contained a section on encouraging deciduous harvesting for coastal BC. This plan recognized that improvements were required on deciduous harvesting and reforestation management strategies. The action plan required government and industry to work together on a regional hardwood management strategy.

6.0 Review of "Hardwood Management in the Coast Forest Region" paper

In February of 2009, the Coast Regional Management Team approved the "Hardwood Management in the Coast Forest Region" with the focus of the strategy on red alder as this is the species with the broadest potential. This paper was developed by a Silviculture Working Group (a collaborative team of industry/government/academics).

The policy change is intended is to support an annual hardwood harvest of approximately 300,000m3/year. In order to support this desired harvest level, a target of establishing up to 1200ha per year has been set for alder stand management.
Overall goals of the Hardwood Management Strategy are: to produce sawlogs to support timber supply, to address timber supply short falls in the medium and long term, to diversify the coastal forestry industry, to address changing market conditions, to maximize land-base utilization, and to use alder to manage for root disease centers as a short-rotation crop (SWG, 2009).

The Hardwood Management Strategy has recognized that there needs to be a variety of management strategies available to provide flexible planning tools for BC's forest professionals. These strategies range from: high investment 'intensive' management regimes; to low investment 'extensive' regimes; and also mixedwood regimes (SWG, 2009). Although the focus of this paper is on mixedwood management, intensive and extensive strategies are important as they can address timber supply shortfalls and components of these strategies are also utilized for alder patches within mixedwood management stands.

6.1 Overview of Intensive and Extensive Management Strategies

The 'intensive' management strategy involves planting at high densities (1400-1600 sph) to take advantage of rapid juvenile growth, followed with active density management/spacing, to maximize the percentage of clear wood which increases log values. (SWG, 2009). The importance of density management of tree form and therefore future log values is apparent in figure 2.

Figure 2. Comparison of tree form between trees planted at 1480 trees per hectare (left) and 290 trees per hectare (right). (Deal and Harrington 2006)

There are many trials on intensive management strategies that are now suggesting that high-value alder sawlogs can be grown in 20-30 year rotations. Although there are substantial silviculture costs associated with this strategy, the shorter rotation length can address the expected short-term timber supply shortfall and there is not expected to be any decrease in the annual allowable cut (AAC) levels compared to conifer management. The Hardwood Management Strategy paper recommends that spacing costs associated with intensive alder management be funded through the Forest Investment Account (FIA) program.

Under the proposed ‘extensive’ management strategy, alder is planted at lower densities (1000-1200 sph) with no planned, spacing treatments. This strategy is expected to produce sawlogs on 30-50 year rotations and is expected to result in a reduced AAC. This strategy has much lower silviculture costs due to reduced planting costs (fewer sph) and no spacing costs, and is well suited for more remote areas that have higher access costs.

6.2 Mixedwood Management Strategies

The Hardwood Management Strategy contains various mixedwood management regimes. Alder regeneration in mixedwood stands can be via natural regeneration or by planting. There is expected to be a decrease in the AAC but due to the complexities associated with mixedwood management, the extent of the AAC decrease is unknown. The mixedwood strategy presents three options: either intimate, successional, or mosaic mixtures.

Prescriptions under the ‘intimate’ mixedwood strategy are designed to grow deciduous and conifer trees intermixed throughout the stand. Stand treatments must be designed to produce high quality sawlogs for both deciduous and conifer species at the same rotation age. This strategy is not endorsed in the Hardwood Management Strategy as there is a lack of data on intimate mixed stands and a concern for the quality of red alder sawlogs produced under this management regime (Wickland conversation, 2009, not cited). The concern is that a mixedwood stand might have alder densities high enough to negatively impact conifer growth but not high enough to promote the production of high quality alder sawlogs. If allowed too much growing space, alder will develop coarse branching which will result in low quality alder logs. There could be a case presented for intimate mixedwood management once there is enough data to support effective conifer/alder spatial density relationships that produce the desired volume and quality of alder and conifer crop trees.

‘Successional’ mixedwood stands are comprised of two canopy layers with alders usually making up the overstory. With this strategy the intent is to harvest the overstory first (without damaging the understory), followed by a second harvest of the understory crop species. The requirement to harvest the overstory without damaging the understory makes this management strategy more appropriate for smaller scale operations such as woodlots. Stratified mixtures have also been used successfully to prevent attacks of spruce tip weevil (*Pissodes strobi*) by growing Alder over Sitka spruce (Deal et al. 2004). At this point, successional mixedwood is not the focus of the coastal mixedwood strategy whereas patch mixedwood strategies are the focus.

The ‘mosaic’ mixedwood strategy involves pure patches of either alder or conifer in various sizes and configurations. The SWG HMS defines these mixedwood patches as:

Macro Patch Mixedwood – large distinct and discreet patches of either pure conifer or pure deciduous (ie ½ block of each);

Meso Patch Mixedwood – medium sized, distinct, and discreet patches of pure conifer or pure deciduous (ie splitting stratum with sections of conifer or deciduous);

Micro Patch Mixedwood – small distinct and discreet patches of either pure conifer or pure deciduous (ie > ½ ha patches intermixed within the stratum). Conversations with Craig Wickland (Chair of the CRIT Silviculture Working Group) revealed that this ½ ha minimum requirement was indented to minimize the amount of red alder growing along patch edges, and provide for a manageable unit. It was stated that a case could be made to reduce this ½ ha minimum requirement.

7.0 Conclusions and Recommendations

As discussed in the above sections of this literature review, broadleaf species, and especially red alder, have a number of timber enhancement values. Alder improves nitrogen levels in low nitrogen soils and is not susceptible to pathogens such as laminated root rot, both qualities leading to improved productivity of associated conifers. Non timber enhancement values include increased biodiversity contributing to overall forest resilience (Buss and Brown, 2008).

Industry and government policy bias for conifer management has been slow to change, but the latest HMS provides forest practitioners with the opportunity to manage red alder operationally. The HMS gives forest managers more options and tools to effectively manage red alder and provides more flexibility for managers to promote mixed stands of alder and conifer.

There are still gaps in our knowledge when it comes to mixedwood management and how complex stands develop through to harvesting. Further research needs to be completed on tree growth and stand development in complex stands. Models need to be developed to enable forest managers to predict growth and yield in these complex stands. Additional research is also required on intimate mixedwood stands. Studies could look at naturally occurring intimate mixes that have high quality alder and conifer and could focus on: the types of sites, the spatial relationship of alder and conifer, tree growth characteristics, and stand density issues. More small scale trials of intimate mixedwood management should be undertaken to set management standards that balance issues such as competition for light, nutritional benefits of alder, and density requirements of alder in intimate mixes needed to produce high value alder and conifer sawlogs.

Policy changes are also required to better reflect our current understanding on alder management and alder/conifer mixed stands. For example, the free growing standards for the maximum number of well spaced alder growing in conifer stands could be increased from 200sph to 400sph on appropriate sites given current research findings. Future policy changes should allow for the intricate and complex spatial mixes of alder and conifer that often occur naturally (e.g. alder leading riparian areas) with less emphasis put on being able to map patches and more emphasis put on crop tree form.

Encouraging and maintaining a resilient and vibrant hardwood industry for coastal BC will require forest managers to employ a variety of alder management strategies.

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