Forests For Tomorrow

Review of Juvenile Spacing Investments

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Executive Summary

The review of FFT juvenile spacing carried out between 2010 and 2016 found that treatments were generally consistent with the strategies and FFT funding criteria in place at the time the prescriptions were written. However the funding criteria and strategies have been evolving over time and it appears many of these past juvenile spacing treatments would not meet the current FFT funding criteria. In addition, many of the more recently completed silviculture strategies in the interior which included JS as a recommended treatment listed it as a low priority relative to other preferred treatments.

Some government district foresters state that changes in harvesting and regeneration practices are resulting in fewer stands that could potentially benefit from juvenile spacing due to lower total establishment densities and/or the planting of genetically improved stock that outperforms the natural regeneration.

Reviews of past stand level financial analyses supplemented with additional analyses completed for this project indicate that there are limited opportunities where juvenile spacing provides a 2% return at the stand level. Red alder stands being managed on short rotation intensive regimes on the coast provide the most opportunities if there are premiums for larger logs. Repressed lodgepole pine stands where repression results in a minimum of a 2 m site index loss are also possible candidates for spacing. Multi-storied dry belt Douglas fir stands outside of mule deer winter range which have over-dense understories and limited overstories can also be candidates for juvenile spacing.

Our analyses of coastal Douglas fir/western hemlock and western hemlock/amabalis fir stands indicated that the spacing must result in both a large enough increase in value and a large enough decrease in harvest costs before spacing provides a 2% return at the stand level. For these stand types obtaining defensible data or expert opinion on differential harvest costs between spaced and unspaced stands on the same sites will be critical to demonstrating the viability of juvenile spacing. It also must be recognized that in some cases spacing will decrease stand value if residual densities are low enough to increase branch sizes, taper or rate of growth beyond critical thresholds.

An additional important finding from the stand level financial analyses completed for this project was that the harvest age at which the juvenile spacing treatment provides a 2% return on investment (assuming decreased harvesting costs in the spaced stand) maybe older than some spaced stands are currently being harvested at or targeted for harvesting under the FFT strategic plans. If harvested too soon, the stand level benefits are not achieved (despite reduced harvesting costs). This presents a significant problem as the government has no control over when stands are harvested.

Risk associated with unknown harvest timing, differences in harvest costs, and changes in log quality makes spacing investments less attractive than other possible uses for limited silviculture expenditures. Increased risk is typically accounted for by requiring a higher return on investment to be demonstrated. However moving the required ROI to 4% negates most spacing opportunities at the stand level.

Forest level justification of juvenile spacing should not be based on the time to reach minimum average (or quadratic mean) diameters. This approach has clearly been demonstrated to be seriously flawed and greatly exaggerates the benefits of spacing.

Preliminary recommended changes to FFT funding criteria are provided. Additional changes will be required following future analyses. Key changes include only using the forest health information from the FS448, increasing the minimum site indices potentially available for treatment, eliminating unrepressed lodgepole pine from the acceptable species and adding criteria for multi-storied drybelt Douglas-fir.

Additional recommendations are provided to improve future analyses and implementation of juvenile spacing opportunities.

TABLE OF CONTENTS

List of Tables

List of Figures

1.0 INTRODUCTION

1.1 BACKGROUND

As part of the Forests for Tomorrow (FFT) program, the Timber Supply Mitigation component focuses on investments to improve the mid-term timber supply in interior management units impacted by Mountain Pine Beetle and Wildfires as well as other areas in the province (Coast; Northwest; Southeast) where land use constraints, or area reductions of the timber harvest land base, has caused increased pressure on the mid-term timber supply. Investments in juvenile spacing treatments have been made to make stands merchantable sooner to address estate level mid-term timber supply gaps or age class imbalance and to prepare stands for future treatments (e.g. fertilization, commercial thinning). Treatments may also provide other benefits in terms of long-term fuel reduction, wildlife habitat, managing tree species composition, and risk reduction from damaging agents (e.g. disease, insects, wind storms, snow press)[1].

Over the last few years there has been very little area juvenile spaced (JS). Currently, there is renewed interest in whether JS should be considered a priority FFT treatment to help deal with strategic issues in many parts of the interior and the coast.

1.2 OBJECTIVES

The objectives of this project are to review recently completed Forest for Tomorrow (FFT) JS treatments to:

1. Assess the consistency with objectives and treatment strategies in silviculture strategies and FFT silviculture funding criteria.
2. Assess the range of stand-level impacts for the main types of JS treatments in terms of yield, value and rate of return on investment.
3. Provide recommendations for changes to FFT silviculture funding criteria and strategic planning for JS.

[1] This information was provided in the background of the request for proposal for this project.

1.3 PROJECT SCOPE

This project provides a broad overview of current JS strategies and operational practices throughout the province under the FFT program. We also provide examples of more in-depth analyses that can be done to support decision making. We do not cover all possible stand types and treatment options in the analyses provided. However the analysis results presented help inform our recommendations for changes to FFT funding criteria and strategic planning for JS.

1.4 TERMS OF REFERENCE

This project was completed by Jeff McWilliams, RPF and Eleanor McWilliams, RPF for Monty Locke, RPF, Ministry of Forests, Lands and Natural Resource Operations (FLNRO), Resource Practices Branch. FLNRO staff reviewing and contributing to this work included Monty Locke, RPF, Louise deMontigny, RPF, Neil Hughes, RPF, Aaron Benterud, RPF, Craig Wickland, RPF, Kevin Telfer, RPF, Kevin Derow, RPF, and Darcy Lillico, RPF. Funding for this project was provided by the Forests for Tomorrow program.

2.0 RESULTS REVIEW OF JUVENILE SPACING

Reporting Silviculture Updates and Land Status Tracking System (RESULTS) data for JS completed by FFT between April 1, 2010 and March 31, 2016 were downloaded and summarized for the following resource districts with related RESULTS codes:

- Chilliwack [DCK]
- Sunshine Coast [DSC]
- Cariboo-Chilcotin [DCC]
- Quesnel [DQU]
- Skeena Stikine [DSS]
- Coast Mountain [DKM]
- Okanagan Shuswap [DOS]
- Thompson Rivers [DKA]
- Selkirk Natural Resource District [DSE]

The above districts were identified by FFT staff as having the largest JS programs. The RESULTS data were downloaded and summarized using the following process:

1. RESULTS – Activities, Forest Cover Silviculture (SILV) and Inventory (INV) information, Opening spatial data were downloaded from the Land and Resource Data Warehouse (LRDW)
2. The report – "RESULTS Report Silviculture Accomplishments, Planning and Project and the report Recipient Silviculture Accomplishment into RESULTS (Licensee)" were exported from the RESULTS interface.
3. Selected the FFT JS activities for funding codes FIL, FIM, FTL and FTM for forest districts of interest completed between 2010 and 2016.
4. Joined the RESULTS openings to the JS Activities table using the opening IDs.
5. Joined the JS Activity table to the JS Activity spatial.
6. Joined to the JS Activity table with the Opening ID to eliminate any overlapping openings.
7. Intersected the JS activity to the FC INV and SILV data.
8. Created a unique ID field.
9. Exploded the intersect layer to remove sliver polygons.
10. Deleted all polygons less than 0.1 ha.
11. Dissolved the intersect layer creating spatial layer with the JS polygons and the INV and SILV data.

Key findings from summary of the RESULTS data were:

- About 7,335 hectares (ha) were treated.
- The majority of the treatment occurred in the fiscal years 2011/12 and 2012/13 (~65%). This coincides with no FFT funding being available in 2013/14 for JS and only funding projects in Community Forests and Woodlots from 2014/15 to 2016/17.
- The majority of the treatments occurred in DCC (~50%) with only ~4% in the Kootenay area (DSE) and ~10% in the Coast Region (DCK and DSC).

- A significant proportion of the treatments after 2012 were completed on woodlots and community forests.
- A significant proportion of the treatments in the Southern Interior Forest Region were in multi-layered dry belt fir stands and in repressed pine stands.

The types of information and the level of detail on pre- and post-treatment stand attributes varied significantly amongst RESULTS submissions. It was determined that the best source of pre-treatment data was from the prescriptions. Therefore we restricted our detailed reviews to those openings with available prescriptions.

Based on a review of the key RESULTS attributes up to 20 openings per district were selected for further review based on the following criteria:

- First selected those with the largest treatment areas.
- Then looked at those that had JS prescriptions attached in RESULTS and had post JS silviculture and inventory data in RESULTS.

Table 1 lists the number of openings selected for further review from each district. The difference between the number of openings greater than the minimum area and the number with available prescriptions and post JS data is the number of openings without prescription or post-JS data submitted to RESULTS (e.g., 19 - 11 = 8 for DSC). The key attributes of the openings selected for further review and analysis from each district are presented in Appendix I.

Table 1. Number of openings selected for further review

Forest District	# of Openings by min area	# of Openings with available prescriptions and post-JS data	Comments on stand type, tenure and JS type
DSC	19 >10ha	9	1 in TFL, 2 in Community Forests, rest in TSA; 3 Dr
DCK	15 >10ha	4	1 in woodlot, rest in TSA
DSS	4 (100%)	4	All in TSA
DKM	16 >30ha	7	Split between TFL and TSA
DCC	18 >60ha	10	3 in Community Forest, 1 in UBC Res For, rest in TSA; all dry belt Fdi
DQU	14 largest	1	All in woodlots
DKA	17 >10ha	10	4 in woodlots, rest in TSA; mix of regular JS and dry belt Fdi
DOS	8 >10ha	6	Mix of TFLs and TSA; all mechanized treatment for max density
DSE	4 (100%)	2	All in Community Forests

We used this information together with the post treatment data available from RESULTS to inform the design of our TASS simulations and financial analyses and also as a basis for questions for district and licensee staff.

3.0 LINKAGE BETWEEN JUVENILE SPACING, SILVICULTURE STRATEGIES AND OTHER PERTINENT STRATEGIC REPORTS

For each district we reviewed the most recent silviculture strategy (or other strategic documents) and summarized the rationale for investments in JS relative to mid-term timber supply or other strategic objectives. In addition we reviewed and summarized the most recent JS stand selection and funding criteria, recent assessments of JS (including Post Incremental Treatment Assessments [PITA]) and available research results. Table 2 summarizes the strategic documents reviewed for this project.

Table 2. Key strategic documents reviewed

Provincial, Regional or Forest District Jurisdiction	Strategic Document(s)
Provincial	Land Based Investment Strategy (FLNRO 2015) Silviculture funding criteria (FLNRO 2014) Silviculture funding criteria (FLNRO 2016)
Coast Forest Region	Field guidelines for the selection of stands for spacing (coastal) (FLNRO 2012a)
Northern and Southern Interior Forest Regions	Field guidelines for the selection of stands for spacing (interior) (FLNRO 2012b)
Coast Forest Region	Hardwood Management in the Coast Forest Region (Silviculture Working Group 2011)
Northwest portion of the Coast Forest Region	Forest investment opportunities in northwest British Columbia (Silverwood Natural Resource Consultants 2016)
DSC	Ministry of Forests, Vancouver Forest Region, Sunshine Coast Forest District Type 2 strategic silviculture analysis (Forest Ecosystem Solutions 2002).
DCK	Fraser TSA silviculture strategy (Type 2) (Cortex Consultants Inc. 2002)
DSS	Bulkley TSA silviculture strategy (Type 1) (Cortex Consultants Inc. 2000a) Kispiox TSA silviculture strategy (Type 1) (Cortex Consultants Inc. 2000b)
DKM	Ministry of Forests, Prince Rupert Forest Region Kalum Forest District Type 2 strategic silviculture analysis (Forest Ecosystem Solutions 2001).
DCC	Type 2 forest level silviculture analysis report for the Williams Lake TSA (Inland Timber Management Ltd. 2000) Williams Lake TSA Type 4 Silviculture strategy (Forsite Consultants Ltd. 2013a) Drybelt Douglas-fir pre-commercial thinning strategy / rationale for the Williams Lake TSA (Day et *al*. 2011) IDF Strategy for Williams Lake and 100 Mile House TSAs (Day et *al*. 2013)
DQU	Quesnel TSA Stand treatment analysis (Timberline Forest Inventory Consultants Ltd. 1998) Quesnel TSA Type 4 Silviculture strategy (Forsite Consultants Ltd. 2013b)
DKA	Kamloops TSA Type 1 silviculture strategy (BC Ministry of Forests and Range 2006) Type 4 silviculture strategy in the Kamloops TSA (Ecora Resource Group Ltd. 2016)
DOS	Okanagan IFPA Type 2 incremental silviculture analysis (Timberline Forest Inventory Consultants Ltd. 2002) Type 4 silviculture strategy in the Okanagan TSA (Ecora Resource Group Ltd. 2013)
DSE	Kootenay Lake TSA Interim silviculture strategy (BC Ministry of Forests 1999b) Arrow TSA Interim silviculture strategy (BC Ministry of Forests 2000) Enhanced Type 2 silviculture analysis Boundary TSA (Timberline Natural Resource Group 2008)
DSC, DCK	PITA reports for 1 opening in DSC and 31 openings for DCK.

3.1 PROVINCIAL AND REGIONAL

The 2015/16 to 2017/18 LBIS (and the 2014/15 to 2016/17 LBIS) (FLNRO 2015) states that under the Timber Supply Mitigation sub-program, fertilization, JS and backlog brushing in the central interior will focus on mitigating mid-term timber supply by targeting these treatments within the "economic fibre-baskets" associated with priority 1, 2 and 3 forest management units. This LBIS also states that fertilization and JS will be carried out on coastal, southeast and northwest management units, with constrained timber supplies and where highest returns-on-investment (ROI) will be achieved, to improve timber availability and value. The RESULTS review of JS activities carried out by FFT between 2010 and March 2016 found that treatments were consistent with geographic parameters stated in the LBIS. Of the subset of openings reviewed in detail (those with prescriptions) some, but not all, of the prescriptions listed an objective of mitigating or improving mid-term timber supply.

From the RESULTS analysis, for the subset of openings reviewed in detail most key stand and site attributes were broadly consistent with the LBIS funding criteria in place at the time (not considering the priority rankings). However in many cases it was uncertain whether the stands selected for treatment would meet the current LBIS funding criteria for competing density criteria. In some cases it appeared from the prescription data that the stands had differentiated enough that the competing density criteria would not be met. For the rest of the prescriptions, consistency with the competing density criteria was un-certain. These variances from current criteria do not necessarily indicate poor past practices in stand selection and prescription development, but do potentially show that some of the treated stands would not be priorities for treatment today.

Currently the Field Guidelines for Selection of Stands for Spacing (FS448a and b) are referenced as complementary standards for stand selection for JS in the LBIS funding criteria. There are several differences between the FS448 and the LBIS funding criteria. For example, for the coast, the FS448 lists top priority stands as those with greater than 1,500 total trees/ha whereas the funding criteria states for Cw, Hw and Ba the number of dominant and co-dominant trees needs to exceed 5,000/ha. This can create inconsistency in stand selection.

Due to challenges with using TIPSY and FAN$IER to model JS prescriptions, FFT does not require that a return on investment (ROI) analysis be completed for each prescription. Instead cost caps (separate caps for the interior and coast) and the LBIS prioritization criteria are used to assess value for money. However there is no analysis available to show that the LBIS ROI threshold will be achieved using the costs caps for the range of stands eligible for treatment using LBIS funding criteria and Field Guidelines for Selection of Stands for Spacing.

While there are several older publications (e.g., Forest Practice Code Spacing Guidebook, Forest Resources Development Agreement Background Report for the Development of Juvenile Spacing Guidelines in BC) which provide general guidance on choosing post treatment densities, much has changed (e.g.; impacts of density on wood quality, resiliency to forest health and treatment objectives) since these documents were developed. None of the current LBIS or the LBIS Silviculture Funding Criteria or the FS448 guidelines provides criteria for post JS densities. Given the importance of residual density in the achievement of stand and forest-level objectives and ROI this lack of guidance for JS prescriptions is potentially significant. For example for the openings reviewed in the RESULTS analysis for DCK and DSC, for JS within similar stand types, there were commonly variances of up to 300 stems per hectare in residual densities without any apparent reasons or rationale (see Appendix I). In addition the majority of post treatment densities for JS in pine stands in the interior were around 1200 stems per hectare which is significantly less than has been recommended to maximize yields, minimize reductions in quality and to reduce impacts of forest health (JS Thrower & Associates 2003, 2005). As will be discussed later in this report, differences in residual density can have a significant impact on the viability of JS treatments.

3.2 SOUTH COAST (INCLUDING DSC, DCK)

The Type 2 Silviculture Strategies for the Sunshine Coast TSA (DSC) (Forest Ecosystem Solutions 2002) and Fraser TSA (DCK) (Cortex Consultants Ltd. 2002) were completed in spring 2002. Both analyses were based on timber supply forecasts which were stable over the next 100 years. Both strategies included an emphasis on a regime based on JS, pruning, fertilization and commercial thinning of managed coastal Douglas-fir (Fd) stands on good to medium sites. The Sunshine Coast strategy also included JS regimes for managed Hemlock/Balsam/Spruce and Cedar-leading stands. Both strategies were based on managing to a target piece size as surrogates for merchantability and quality (value) and on the premise that JS of Fd stands was required to develop preferred candidates for fertilization.

For the Sunshine Coast TSA, JS of Fd-leading stands was shown to have a minimal (<5%) positive impact on timber supply after about 100 years. For the Fraser TSA, JS and fertilization was lumped together in a scenario which showed a short term supply increase of about 19%. However comments in the report indicate that the vast majority of the benefit came from the fertilization. Neither strategy included stand or forest-level analysis of the financial viability of the preferred regimes.

For the subset of openings selected for detailed review in DSC and DCK, the objectives and stand and site attributes were broadly consistent with the silviculture strategies in place. However this conformance should provide limited comfort that the treatments met strategic guidelines set by the silviculture strategy.

Since these silviculture strategies were completed a lot has changed in terms of forest policy, forest land base reductions, and management of second growth timber in coastal timber supply areas. For example under the Forest and Range Practices Act (enacted in 2002) government no longer controls when stands can be harvested by licensees. For treatments such as JS where harvest timing commonly has a significant impact on achievement of ROI, this can lead to substantial uncertainty in the viability of the investment. In addition, due to the recent creation of new tenures and addition constraints, the TSA timber harvesting land base on the south coast has become smaller and more fragmented. Together with economic pressures this has led to extensive harvesting in accessible second growth stands.

There is also updated information on the trade-offs between growing individual stems as quickly as possible to achieve a target pieces size versus the reduced quality and value associated with these practices (JS Thrower & Associates 2003, 2005).

A stand-alone hardwood strategy was produced for the Coast Forest Region (Silviculture Working Group 2011). This strategy included intensive, extensive and mixedwood management options for red alder (Dr), big leaf maple and birch. The Intensive option was primarily for short rotation management of Dr by planting at high densities and JS. This regime was largely based on practices used by Weyerhaeuser in Pacific Northwest.

From the RESULTS analysis, of the subset of openings selected for further review in DSC, several JS treatments occurred in Dr stands consistent with the intensive regime of the hardwood strategy.

3.3 NORTH WEST (INCLUDING DKM, DSS)

The Type 2 Silviculture Strategy for the Kalum TSA (DKM) was completed in fall 2001 (Forest Ecosystem Solutions 2001). Type 1 Silviculture Strategies were completed for the Bulkley and Kispiox TSA's in 2000 (Cortex Consultants Inc. 2000a, 2000b). These Type 1 strategies do not have enough detail about favoured regimes and their potential impacts on timber supply or value to warrant comparison with the JS treatments subsequently implemented in these areas.

The Kalum Type 2 strategy was based on a timber supply forecast which was stable in the short term (first 40 years) and then stepped up by about 50,000 cubic meters per year for rest of the simulation (>150 years). The primary strategy was to JS, prune and commercial thin western hemlock (Hw) leading managed stands. This strategy was based on managing to a target piece size as surrogates for merchantability and quality (value). The timber supply impact of this regime was minimal (<2%) from about 60 to 120 years and then larger after this. This Type 2 strategy did not include stand or forest-level analysis of the financial viability of the preferred regime.

A stand-alone report on forest investment opportunities in northwest BC was produced in 2016. This report included:

- A review of the second growth supply and quality needs to support new milling capacity.
- A comparison of yields between modelled estimates using TIPSY and field estimates for JS stands.
- A forecast of available harvest flows to again assess the supply prospects for new manufacturing capacity.

This report indicates that spacing can make second growth stand merchantable sooner increasing the opportunities for a new processing facility to be built in the region. However the report did not include stand or forest-level analysis of the financial viability of the assessed regimes. In addition the analysis was based on managing to different target average diameters as surrogates for merchantability and quality (value). Given the past history of extensive JS and the preferred plan of significant future JS, the results of the analysis are strongly linked to the target diameters used. The challenges of using this approach to assessing the impacts of JS are discussed in more detail in Section 6 and clearly documented in the 1999 Ministry of Forests document "Guidelines for developing stand density management regimes".

From the RESULTS analysis, of the subset of openings selected for further review in DKM, the objectives and stand and site attributes were broadly consistent with the existing Type 2 silviculture strategy. However due to the lack of detailed stand and forest-level analysis of JS in the Type 2, this conformance should provide limited comfort that the treatments met strategic guidelines set by the silviculture strategy and were proven to be viable.

3.4 CARIBOO (DCC, DQU)

A Type 2 Silviculture Strategy for the Quesnel TSA (DQU) was completed in fall 1998 (Timberline Forest Inventory Consultants 1998) and a Type 4 strategy was completed in 2013 (Forsite Consultants Ltd. 2013b). As there was only one available prescription to review for DQU it was felt there was limited utility in a detailed assessment of these silviculture strategies. In short the available prescription was for JS in lodgepole pine (Pli) leading stand which was generally consistent with silviculture strategy in place at the time.

A Type 2 Silviculture Strategy for the Williams Lake TSA (DCC) was completed in spring 2000 (Inland Timber Management Ltd. 2000) and a Type 4 strategy was completed in fall 2013 (Forsite Consultants Ltd. 2013a). All of the reviewed JS openings for DCC under this project were in multi-storied dry belt interior Douglas-fir (Fdi) stands. As a significant portion of the JS treatments occurred prior to 2013 and the Type 2 strategy did not list JS in dry belt Fdi stands as preferred regime, in 2011 a specific rationale for JS in these stand types was developed (Day et *al*. 2011). This rationale referenced stand-level growth and yield (with PROGNOSIS) and financial analysis completed in 2010 for Tolko Industries Ltd (B.A. Blackwell and Associates Ltd. 2010). Subsequently to support the Type 4 strategy, an IDF Strategy was produced in 2013 (Day et *al*. 2013). The Type 4 strategy recommended an annual treatment target of about 470 hectares for dry belt Fdi JS. However there is no detailed forest-level analysis provided to rationalize this investment or support the selection of this target.

From the RESULTS analysis, the subset of openings selected for detailed review in DCC had objectives and stand and site attributes that mostly consistent with the 2011 Dry Belt Fdi Rationale and the 2013 IDF Strategy. However some of the stands treated appear to have >10m^2 of mature overstory basal area. These stands are not consistent with the criteria in the 2013 IDF Strategy.

3.5 SOUTHERN INTERIOR (DKA, DOS)

A Type 1 Silviculture Strategy for the Kamloops TSA (DKA) was completed in spring 2006 (BC Ministry of Forests and Range 2006) and a Type 4 strategy was completed in spring 2016 (Ecora Resource Group Ltd. 2016). All of the reviewed JS openings for DKA under this project were completed before 2016 so were to be guided by the Type 1 strategy. This strategy lists several types of JS as preferred strategies including treatment of dry belt Fdi, over-dense Pli, dense Fdi/Sx to set up fertilization and potentially commercial thinning. By nature this Type 1 analysis does not include stand or forest level growth and yield or financial analysis to support the selection of preferred regimes. The Type 4 strategy does not include any JS but includes ecosystem restoration and partial harvest in dry belt Fdi stands. It is not clear from the strategy but JS could be part of some ecosystem restoration plans.

From the RESULTS analysis, the subset of openings selected for further review in DKA had objectives and stand and site attributes that were broadly consistent with the Type 1 strategy. However given the lack of detailed stand and forest-level analysis provided to rationalize this investment, this broad consistency is not considered significant. In addition some of the treated dry belt Fdi stands appear not to be consistent with the criteria from the 2011 Dry Belt Fdi Rationale from the Cariboo region.

JS treatments selected for review in the Okanagan TSA (DOS) were within the TSA, several TFL's owned by Weyerhaeuser Ltd. and woodlots and community forests. All were in stands above maximum densities. A Type 2

Silviculture Strategy for the Okanagan IFPA was completed in spring 2002 (Timberline Forest Inventory Consultants Ltd. 2002) and a Type 4 strategy was completed in summer 2013 (Ecora Resource Group Ltd. 2013). In addition silviculture strategies exist for several of the TFLs where the JS treatments occurred. All of the strategies reviewed contained strategies for maximum density JS treatments and all of reviewed prescriptions were generally consistent with the strategies. The Type 4 strategy recommended an annual treatment target of about 724 hectares for JS of dense Fdi and spruce leading stands and over-dense Pli stands. However JS was listed as the lowest priority for funding in the strategy and there is no detailed forest-level analysis provided to rationalize this investment or support the selection of this target.

3.6 KOOTENAYS (DSE)

JS treatments selected for review in DSE were within the Kootenay Lake TSA. A Type 1 Silviculture Strategy for the Kootenay Lake TSA was completed in January 1999 (BC Ministry of Forests 1999b). This strategy lists JS as a preferred treatment in several different stand types. By nature this Type 1 analysis does not include stand or forest level growth and yield or financial analysis to support the selected treatment regimes.

From the RESULTS analysis, the subset of openings selected for further review in DSE had objectives and stand and site attributes that were broadly consistent with the Type 1 strategy.

3.7 REVIEW OF PITA RESULTS (DCK, DSC)

PITA was developed to provide a consistent methodology for assessing previously completed incremental silviculture treatments such as JS. The current standards for PITA (Coastal) were finalized in March 2012 (FLNRO 2012c). A goal of this project was to review and summarize the key findings from a selection of the PITA reports for JS treatments within districts with recent JS activities.[2] As of August 2016, 1 PITA was available for DSC and 31 reports were available for DCK. It should be noted that all of these reports were for treatments which occurred before 2010.

Based on a review of selected PITA reports for JS, the following are some generalized, frequently noted observations and recommendations;

- Most treatments did not have associated controls. As a result assessment of treatment response relied on modelling (with TIPSY and FANSIER) which makes the results very uncertain.
- Modelling of mixed species stands and some JS treatments is commonly beyond the capabilities of TIPSY.
- Treatment outcomes relative to objectives were mixed with some being okay and others being poor. Very few treatments were rated as successful.
- Of the JS treatments which were rated as poor, commonly the residual densities were too low which reduced yields and created poor quality logs (poor form, heavy branching, high rates of growth).

It is not appropriate to infer anything about the population of JS openings reviewed under this project based on the results of these PITAs. Over time there have clearly been some changes in JS practices, most specifically with respect to higher residual densities. However the PITA results suggest that there are many details that must successfully be addressed in JS prescriptions and implementation in order to achieve the preferred results upon which the investments are based on.

[2] The project scope and timing did not allow for a review of PITA methodology. As such, findings summarized here should not be interpreted as an endorsement of this methodology.

4.0 FEEDBACK FROM GOVERNMENT AND LICENSEE STAFF ON JUVENILE SPACING INVESTMENTS

To confirm planning and practices for JS in different stand types and to understand local perspectives on objectives and constraints associated with JS, feedback was received from a number of district FLNRO staff[3]. In addition feedback was received from Coast Mountain Hardwoods relative to JS in Dr stands and from research staff relative to recent density management research results[4].

The following questions were asked during the interviews with district staff:

- What, if any, roles do you or your district colleagues have in overseeing FFT programs such as JS?
- How does JS contribute to meeting identified strategic objectives in the area?
- How are JS treatments prioritized?
- Do you have any thoughts on FFT JS treatment funding criteria?
- What opportunities and challenges are associated with future JS?

Following is a summary of some of predominant responses to these questions and other issues brought up by district staff:

- Many districts do not have direct, significant involvement in the FFT program and as a result have limited involvement in prioritization, planning or implementation of JS treatments. In these situations either the TSA in question is a low priority for FFT funding and/or the regions or the Administrator (Pricewaterhouse Coopers LLP) provide the majority of the oversight for FFT activities.
- In several districts where staff had an interest in future JS, they had looked in the field for preferred candidates for JS which met the current selection criteria but could not find much area to treat. Staff from the coast and interior noted that planting with genetically improved stock and reduced natural infill were limiting the need to JS (even if this was a desired treatment). Several staff indicated the priority for investment should be to establish higher initial densities on good to medium sites.
- Some staff believe that a requirement for success JS is that there must be enough competition to justify the intervention
- Some staff noted the importance of JS for providing work opportunities for First Nations people.
- Some staff believe that repression Pli JS should be a priority
- Some staff believe that dry belt Fdi JS should be a priority; even to promote achievement of non-timber objectives.
- Some staff on the coast believe that JS should focus on ensuring that western red cedar (Cw) is promoted in mixed stands (there is ongoing work to assess these opportunities as part of the Arrowsmith TSA Integrated Resource Management Plan).

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[3] The staff to be interviewed were suggested by the government contract administrator

[4] See Appendix II for a list of people interviewed for this project.

According to research staff, there are a number of JS assessment projects currently underway and recently completed (in the Soo TSA and Haida Gwaii). No results are yet available for the on-going project in the Soo TSA. The report for the assessment of JS on Haida Gwaii was not reviewed as this geographic area was not within the terms of reference for this project. Prior results of JS research have been incorporated into the development and validation of TASS.

Feedback from district, licensee and research staff was also used to confirm the ranges of stand and site inputs to be used for the TASS growth and yield analysis and the range of in cost and revenue assumptions for the financial analyses.

5.0 SUMMARY OF RECENT JUVENILE SPACING ANALYSIS

5.1 LODGEPOLE PINE

The results of a large project examining Pli product yields in relation to final stand density were published by Forintek in 1995 (Middleton et *al*., 1995). This work was based on trees selected from 95 year old stands on good sites in southeastern BC as there were no mature plantations to study at the time. It is presumed that the stands, given their age, were fire-origin, and the initial densities and stand development pathways to reach the densities at age 95 are unknown. The study indicated that for Lodgepole pine grown on good sites that the optimal combination of lumber yield and grade would be obtained by targeting a medium (approximately 1100 stems/ha) final density. The study did not include any financial analyses of spacing treatments to achieve these densities.

Between 2003 and 2005, JS Thrower and Associates Ltd completed three projects for Weyerhaeuser that analyzed the stand and forest level benefits of juvenile spacing Pli. These were done for TFL 15 (JS Thrower & Associates 2003), the Merritt TSA (JS Thrower & Associates 2005a), and the Okanagan TSA (JS Thrower & Associates 2005b). The following information is paraphrased from the executive summaries of these reports. The stand level analyses were similar for all projects, while the forest level analyses examined the specific conditions in each management unit.

The BC Ministry of Forests developed a process in 1999 to compare the impacts of different stand density management regimes considering biological, economic, and forest-level impacts (often referred to at the time as the Chief Forester's process) (BC Ministry of Forests 1999). This process was used to examine the impacts of different options to juvenile space Pli stands in TFL 15, Merritt TSA and Okanagan TSA.

The best available science and information was used to estimate stand and forest-level impacts of different spacing options. The regimes tested included no spacing (with and without height growth repression of 2 m) and spacing to 1,200/ha, 2,200/ha and 3,200/ha using maximum density thresholds of 10,000/ha and 20,000/ha. Stand growth and yield was modelled with TASS in conjunction with models developed by Weyerhaeuser to predict wood quality and lumber recovery. Forest-level impacts were then tested with forest estate models and the base case assumptions from the most recent timber supply analyses.

The stand-level results show little impact of spacing on total and net merchantable volume (12.5 cm dbh limit) and no effect on rotation age. Spaced stands showed proportionally more volume in larger diameter trees, however, increased taper plus larger knot size lead to lower recovery of high value lumber products (MSR grades). Consequently, the unspaced treatment showed the highest stand value. Spacing decreased stand value. This obviously made spacing not financially viable under any of the tested costs, discount rates and product values. In addition spaced stands produced fewer snags and less coarse woody debris than unspaced stands. In terms of potential forest health impacts, high-density stands have a buffer or extra trees to compensate for losses, whereas low density stands have no buffer for unexpected mortality and the loss of even a few trees may significantly reduce stand yield.

The forest level analyses showed that spacing did not have a significant effect on the flow of merchantable volume but did dramatically decrease the flow of high-grade logs and lumber. Minimum harvest age criteria in the forest level analyses were based on the achievement of a minimum merchantable volume. Achievement of a minimum diameter was not used, so there were minimal differences in the minimum harvest ages between spaced and unspaced stands.

5.2 REPRESSION DENSITY SPACING

A FFT funded review of repression density spacing was completed in the spring of 2016 (ASCE 2016). The goal of the project was to develop decision support aids to help administer FFT funded treatments in young high density stands of Pli, western larch (Lw) and interior Douglas-fir (Fdi). The project scope was restricted to stand level decisions with the assumption these decisions would be developed under the appropriate forest level analyses indicating that treatment of repressed stands is a priority at the forest level.

The key points from the literature summary were:

- "Repression has been commonly observed in high density fire-origin Pli stands, and much more infrequently in very high density fire-origin Lw stands.
- Repression has not been observed in high density fire-origin Fdi.
- Repression has not been observed in high density post-harvest regenerated stands of any species.
- Lw, if established early, has rapid early height growth and will generally overtop and dominate other species on many (not all) sites.
- Repressed Pli stands grow and develop in a similar manner to unrepressed stands but at a slower rate.
- Repression can be modelled as a loss in site index.
- The magnitude of repression varies with initial stand density and site quality.
- Evidence suggests that the earlier the treatment of repression the greater the mitigation of the site index loss.
- There is not sufficient information to predict absolute values at which repression occurs in fire-origin Pli stands. Therefore, practitioners should acknowledge this uncertainty in decisions regarding treatments of repressed and potentially repressed stands."

TASS simulations of seven different types of spacing treatments and financial analyses were used to develop "breakeven" treatment costs. These represent the maximum amount that can be spent on a treatment to provide a positive return at 2%. They are a function of the realized site index after treatment, and the site index lost due to repression if the stand is not treated. In all cases a loss of 2m site index or more was needed to provide a 2% return on investment and in many circumstances a loss of 4m or more was required.

The report also includes a treatment decision key and proposed revised FFT funding criteria.

5.3 DRYBELT DOUGLAS-FIR

Several Forest Investment Account (FIA) funded strategic studies were completed for dry belt Fdi stands in the Williams Lake and 100 Mile House TSAs between 2009 and 2010.

The objective of the main overarching project was to test and compare the utility of two different stand classification approaches to producing silviculture prescriptions, regimes and strategies for the Tolko IFPA area (excluding Mule Deer Winter Range [MDWR]). This project generated four reports (completed by DWB Consulting Services Ltd., Tesera Systems Inc. and BA Blackwell and Associates Ltd. for Tolko Industries [acting as a Recipient for FIA]):

1. Stand identification, delineation of Stand Types, Ground comparisons, Application of Stand Structure Classification and identification and description of Silviculture Regimes (DWB et *al*. 2009)
2. Stand-level Modelling (BA Blackwell and Associates Ltd. 2010)
3. Forest Estate Modelling (DWB et *al*. 2010)
4. Project Summary

Another report was completed for the MDWR portion of the Tolko IFPA (DWB Consulting Services Ltd. 2010).

The key findings from the reports on dry belt Fdi stands not in MDWR were (paraphrased from the Executive Summaries, Assumptions and Recommendations sections):

- The 17 class Tolko Stand Structure Classification System was a suitable platform upon which to develop stand-level silviculture regimes for dry belt Fdi and has the potential to be used to operationally classify stands by treatment regime.
- Key incremental (not involving significant commercial volume removal) treatment regimes identified for dry belt Fdi stands were:
    - JS (or pre-commercial thinning); to make stands operable sooner by reducing competition, focusing growth on preferred stems and by increasing resistance to forest health agents.
    - Overstory Removal; where stocking and distribution of Layer 1 tree are such that the understory is stagnating but the volume and quality of the overstory is not adequate to support a commercial harvest. Without some removal of the overstory, JS is not considered viable in these stands.
- Of the about 6500 ha of dry belt Fdi stands field assessed for the project (the pilot area was specifically chosen for having known treatment opportunities), about 27% (1760 ha) was estimated to be suitable for JS and 31% (1990 ha) needed overstory removal before or in combination with JS.
- With the following key assumptions:
    - midterm sawlog and peeler values of $65 and 80 per cubic meter respectively
    - minimum merchantable harvest volume of 50 cubic meters per ha per entry
    - harvest costs [including silviculture but excluding overhead] of about $34 to 36 per cubic meter
    - forest health reduced volume by 10% in un-treated stands and 5% in JS stands and
    - fire risk reduced volume by 1% in un-treated stands and 0.5% in JS stands

Stand-level growth and yield (with $PROGNOSIS_{BC}$) and financial analysis (with a 2% ROI threshold) found that JS was viable under the following conditions (based on the next harvest entry being done within a defined period in the mid-term which varies by stand type);

1. Juvenile (Layer 3 and 4) densities >2000sph with poor to moderate differentiation and
2. Layer 1 basal area of <10m^2 per ha and
3. All-in (including planning and implementation costs) treatment costs <$1200/ha

- Stand-level analysis also found that overstory removal in stands with >10m^2 per ha of basal area combined with JS was viable in certain stand types assuming that some commercial timber could be removed and off-set some of the treatment costs. However no specific criteria were provided for viable treatments under this type of regime.
- Forest estate modelling of the pilot area found that by performing the recommended suite of treatments (primarily JS and overstory removal and JS) in the short term, that timber supply can be improved in the mid-term and that over about a 120 year planning horizon, a positive net present value (with a 2% discount rate) can be achieved.
- Finally these reports recommended that, as the effectiveness and viability of the suggested regimes are sensitive to variations in stand structure, more work was required to classify and inventory these stands before more extensive investments in planning and treatments could be made.

The key findings from the report on the opportunities for JS in dry belt Fdi stands within MDWR were (paraphrased from the Executive Summary, Assumptions and Recommendations section);

- With the following key assumptions:
  - same assumptions as for the non-MDWR analysis for log prices, minimum harvest volume, costs and treatment impacts on forest health and fire losses and
  - a non-timber value of $1000 per hectare (for ecological and social services) for treatments which allow the BDq (B[minimum basal area .7.5cm]= 18m^2 per hectare; D{maximum diameter]=52.5cm; q[diameter class density quotient]=1.4) objectives to be achieved continuously through the planning horizon

Stand-level growth and yield (with $PROGNOSIS_{BC}$) and financial analysis (with a 2% ROI threshold) found that JS and overstory removal with JS were not viable for the three stands assessed[5] within the Low Stand Structure Objective portion of U-5-003. However sensitivity analysis found that somewhat lower treatment costs and/or higher log values would make some of the treatment regimes viable. Another key un-certainty in the analysis was the valuation of non-timber services.

[5] Target stands were geographically and administratively appropriate within the project area, located in the Low crown closure habitat class, previously harvested, with enough mid-sized and larger stems to produce a commercial harvest in the mid term, meeting both MDWR basal area targets and finally, it would have enough small stems to benefit from spacing/cleaning.

Subsequently, as previously noted, a dry belt Fdi rationale (Day et *al*. 2011) and an IDF silvculture strategy (Day et *al*. 2013) were developed which were in part based on the results of the 2010 dry belt Fdi analysis projects completed for Tolko.

6.0 STAND LEVEL FINANCIAL ANALYSES USING TASS SIMULATIONS

6.1 OVERVIEW

Current FFT procedures do not recommend the use of TIPSY and FAN$IER to determine the internal rate of return for evaluation of JS (FLNRO 2013). Instead cost caps are provided in the silviculture funding criteria (FLNRO 2016) of $2,035/ha on the coast and $1,300/ha in the interior. We chose to use TASS and site value analysis for our stand level financial analyses for the following reasons:

1. TIPSY does not have an option for modelling stands that are composed of both planted and ingress trees. To approximate yields from stands with both planted and ingress trees, different weightings of planted and natural curves are used. Stands with both planted and ingress trees can be modelled in TASS.
2. The TIPSY database does not include simulations for mixed-species stands. Yield curves for mixtures are simply a combination of the yields for component species weighted by the initial species proportions. Mixed species stands can be simulated in TASS II with the caveat that calibration of the model for mixtures is ongoing with the development of TASS III.
3. TASS has a custom bucking routine which allowed us to use generic industrial log sorts and pricing for second growth timber. We feel these better represent the values being recovered from these stands.
4. Site value is the best option for comparing treatments that may have different rotation lengths. A primary reason for juvenile spacing in many prescriptions we reviewed was to "reduce rotation length". Internal rate of return is not the best measure for assessing investment choices when treatment options have different rotation lengths. (See the discussion on page 9 of the FFT guidance document (FLNRO 2013)).
5. Producing site value versus stand age curves allows for comparison of treatment options across a range of potential harvest ages. Often treatment "A" has a higher site value than "B" for a given range of harvest ages, and "B" is greater than "A" for another range of harvest ages. In other words the site value curves often cross and it is important to understand that this happens.

TASS II simulations were done for three different species combinations to supplement the analysis work that has been done in the past (Section 5):

- Coastal Douglas-fir (Fd) and western hemlock (Hw) mixtures to assess spacing on the south coast
- Western hemlock and amabilis fir (Ba) mixtures to assess spacing in the northwest.
- Red alder (Dr) to assess spacing opportunities on the south coast.

For each species combination simulations were done across a range of site indices and initial densities combined with different post-spacing densities and spacing ages. The ranges of pre- and post-spacing[6] stand conditions were based on the RESULTS review and feedback from regional, district and licensee foresters. All simulations included output of logs bucked to industrial sorts. Treatment options were compared using site values (details in

[6] Post spacing densities do not include "ghost trees"

Appendix III) using ranges of costs and revenue assumptions to test the sensitivity of the investment decision to these factors.

In the financial analyses we use a fixed harvest cost assumption (a constant $/m^3 over time). We acknowledge this is somewhat simplistic. There are multiple factors that determine harvest costs including equipment type, terrain, season, and stand characteristics. In addition harvest costs will vary over the stand age as a function of the harvestable volume and the distribution of piece sizes. However, we have limited recent data to inform how these costs vary over time for the types of stands we are simulating. To address this we performed sensitivity analysis, including varying the costs between spaced and unspaced stands. For the stand types we simulated we are not aware of any recent data comparing harvest costs between spaced and unspaced stands. We therefore asked several industry foresters with experience in harvested second growth stands on the south coast.[7] Their opinions were that cost difference ranged between 0 and $5/m^3. Based on this we set the range for the sensitivity analysis from plus or minus $0 to $10/m^3 to ensure we bracketed the extreme situations.

6.2 COASTAL DOUGLAS-FIR AND WESTERN HEMLOCK

6.2.1 TASS II SIMULATIONS

The matrix of TASS II runs done for Fd and Hw are summarized in Table 3. All spacing was simulated as spacing from below with the objective of leaving well distributed trees with a preference for Fd. Example images from the TASS II simulations for 1000 Fd planted plus 3000 Hw ingress on Fd site index 31 are shown with and without spacing to 650 sph in Figure 1.

Table 3. TASS II run matrix for Fd-Hw mixtures.

Variable	Levels	# of Levels
Species Mix	Fd + Hw	1
Fd Site Index	28, 31, 34 m	3
Hw Site Index	24.7, 27.4, 30.1 m (from Fd-Hw SI conversion equation)	
Fd Regen	800, 1000, 1200 planted (no genetic gain)	3
Hw Regen	3000, 5000, 7000 naturals with a random spatial distribution	3
Spacing	None, leave 650 sph, leave 750 sph	3
Spacing age	SI 28 age 13, SI 31 age 12, SI 34 age 11	
OAFs	OAF1 = 0.85, OAF2 = 0.95	1
Total Runs		81

[7] Rob Sandberg, RPF, Teal Jones Group, Joe LeBlanc, RPF, Interfor Corporation, Rick Monchak, RPF, Timberwest Forest Corp.

6.2.2 BUCKING SIMULATION

The industrial sorts summarized in Table 4 and Table 5 were used to for the bucking simulation. Each tree was bucked between a 30 cm stump and a 10 cm top diameter to generate the optimum value using the base case log values. The minimum recoverable log length for both Fd and Hw is 5m based on current industrial practice.

Table 4. Fd industrial log sorts.

Sort	Min Top (cm)	Length (m)	Base Value	Low Value	High Value
Sawlog/ Peeler	38	13	$120.00	$60.00	$150.00
Sawlog/ Peeler	38	11	$120.00	$60.00	$150.00
Sawlog/ Peeler	38	8	$120.00	$60.00	$130.00
Large Gang	30	13	$90.00	$80.00	$130.00
Large Gang	30	11	$90.00	$80.00	$130.00
Large Gang	30	8	$90.00	$80.00	$100.00
Small Gang	20	13	$70.00	$60.00	$110.00
Small Gang	20	11	$70.00	$60.00	$110.00
Small Gang	20	8	$70.00	$60.00	$80.00
Chip'n'Saw	12.5	13	$55.00	$55.00	$80.00
Chip'n'Saw	12.5	11	$55.00	$55.00	$80.00
Chip'n'Saw	12.5	8	$55.00	$55.00	$80.00
Chip'n'Saw	12.5	6.3	$55.00	$55.00	$80.00
Chip'n'Saw	12.5	5.1	$55.00	$55.00	$80.00
Pulp	12.5	5	$35.00	$35.00	$35.00

Table 5. Hw industrial log sorts.

Sort	Min Top (cm)	Length (m)	Base Value	Low Value	High Value
Sawlog	38	13	$70.00	$60.00	$110.00
Sawlog	38	11	$70.00	$60.00	$110.00
Sawlog	38	8	$70.00	$60.00	$80.00
Gang	20	13	$60.00	$50.00	$90.00
Gang	20	11	$60.00	$50.00	$90.00
Gang	20	8	$60.00	$50.00	$70.00
Chip'n'Saw	12.5	13	$50.00	$50.00	$75.00
Chip'n'Saw	12.5	11	$50.00	$50.00	$75.00
Chip'n'Saw	12.5	8	$50.00	$50.00	$75.00
Chip'n'Saw	12.5	6.3	$50.00	$50.00	$75.00
Chip'n'Saw	12.5	5.1	$50.00	$50.00	$75.00
Pulp	12.5	5	$40.00	$40.00	$40.00

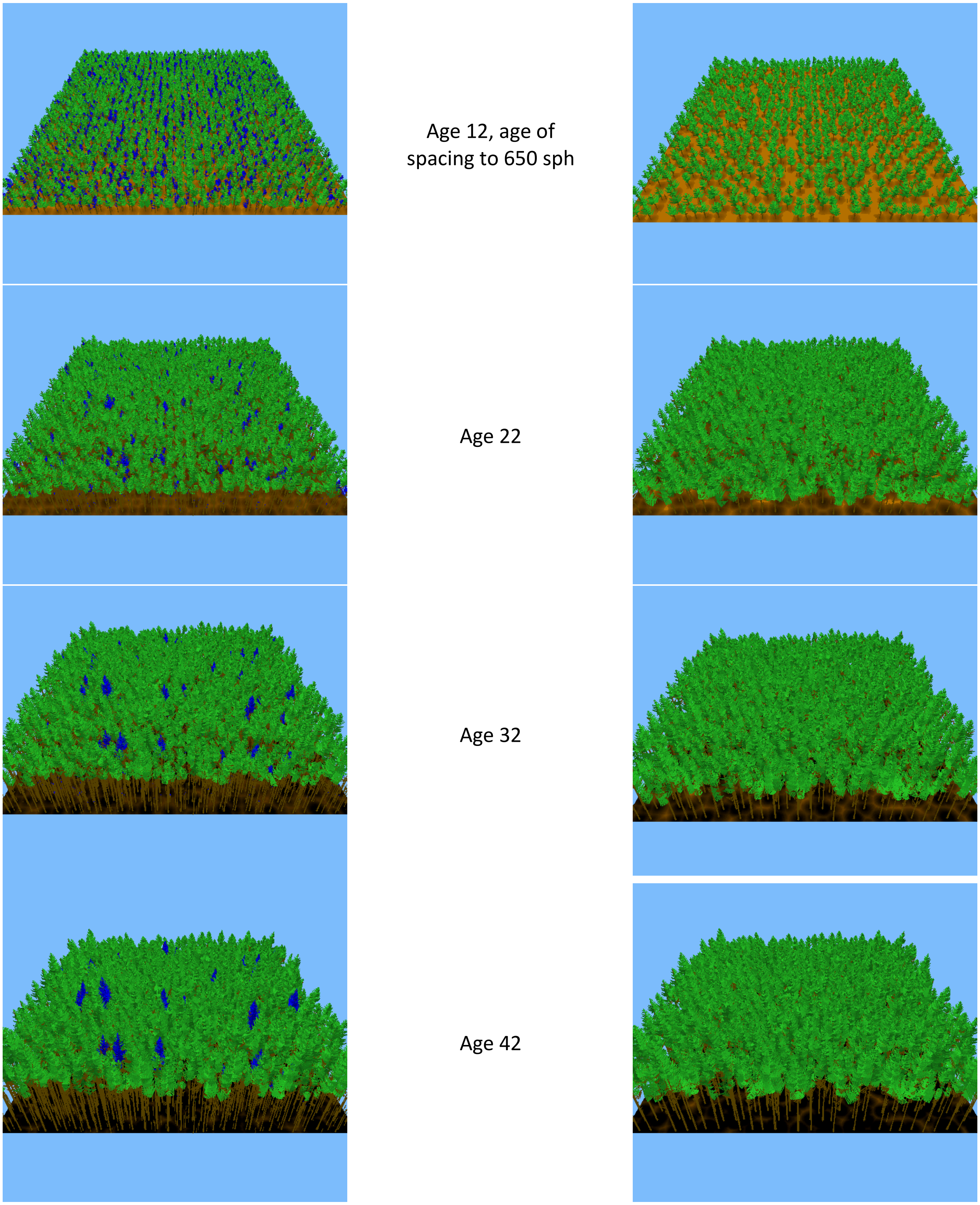

Figure 1. TASS II images of 1000 Fd (green) planted with 3000 Hw (blue) ingress, Fd SI 31, unspaced (left) and spaced to 650 sph (right).

6.2.3 REVENUE AND COST ASSUMPTIONS

The FFT prescribed discount rate of 2% was used to evaluate spacing treatments. Planting costs per tree (Table 6) varied by density. Average, low and high (all found[8]) juvenile spacing costs of $1,750, $1,500, and $2,000 were used. The cost variation primarily reflects differences in access and slope. Harvest costs were set at $50/m^3 for the base case and varied between $45 and $55/m^3. Harvest costs are for ground-based tree to truck costs with variations reflecting differences in access and potential impacts of juvenile spacing. Log values were varied according to the values in Table 4 and Table 5. Base case values represent domestic prices for 2014 and 2015. Low values are for fast grown trees with high taper, wide rings and large knots. These attributes cause the value of sawlogs and gang logs to be downgraded. High values are reflective of good quality logs (low taper, moderate rate of growth and medium to small knots) suitable for export to Japan (the price increases are net of offshore transport costs).

Table 6. Fd planting costs.

Planting	Cost per tree		
Density	Base	Low	High
800	$0.80	$0.70	$0.90
1,000	$0.78	$0.68	$0.88
1,200	$0.76	$0.66	$0.86

6.2.4 GROWTH AND YIELD RESULTS

An example of the common pattern of stand development in terms of volume between an unspaced and spaced stand is shown in Figure 2. The example presented is for Fd site index 31, 1000 Fd planted per hectare and 5000 Hw ingress per hectare. In this example, the spaced stand was spaced to 650 trees/ha at age 12. As demonstrated in Figure 2 whether or not the spaced or unspaced stand has more volume at any given point in time is dependent on the volume definition. In terms of total standing volume (no diameter limit), and a diameter limit of 12.5 cm, the unspaced stand always has more volume. If the diameter limit is raised to 22.5 or 32.5 cm, then the spaced stand has more volume.

The quadratic mean diameter versus age for the same stands is shown in Figure 3. Using this simple statistic to determine harvest ages is clearly misleading when compared to the information provided by the complete diameter distribution, the volume above defined diameter limits, or expected log distributions. The diameter distribution of the same example stands at age 50 is shown in Figure 4. Note that there are large trees in the unspaced stand. The quadratic mean diameters of the spaced and unspaced stand at age 50 are 27.3 cm and 33.8 cm. The log distributions at age 50 are shown in Figure 5.

8 All found costs include prescription, treatment, survey and overhead costs.

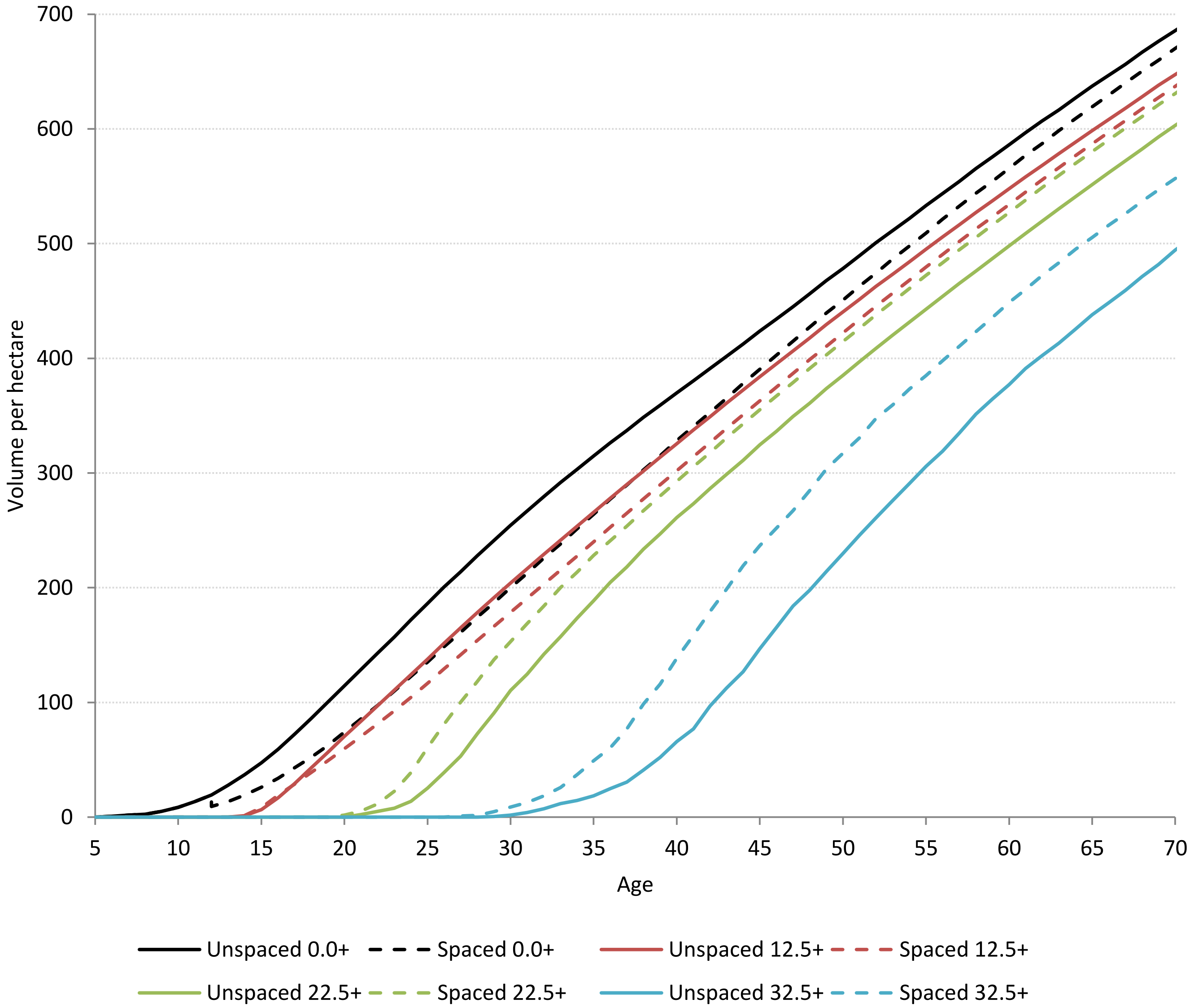

Figure 2. Volume/ha at different merchantable limits for a spaced and unspaced stand. Fd SI 31, 1000 Fd planted, 5000 Hw ingress. Spacing to 650 trees/ha at age 12.

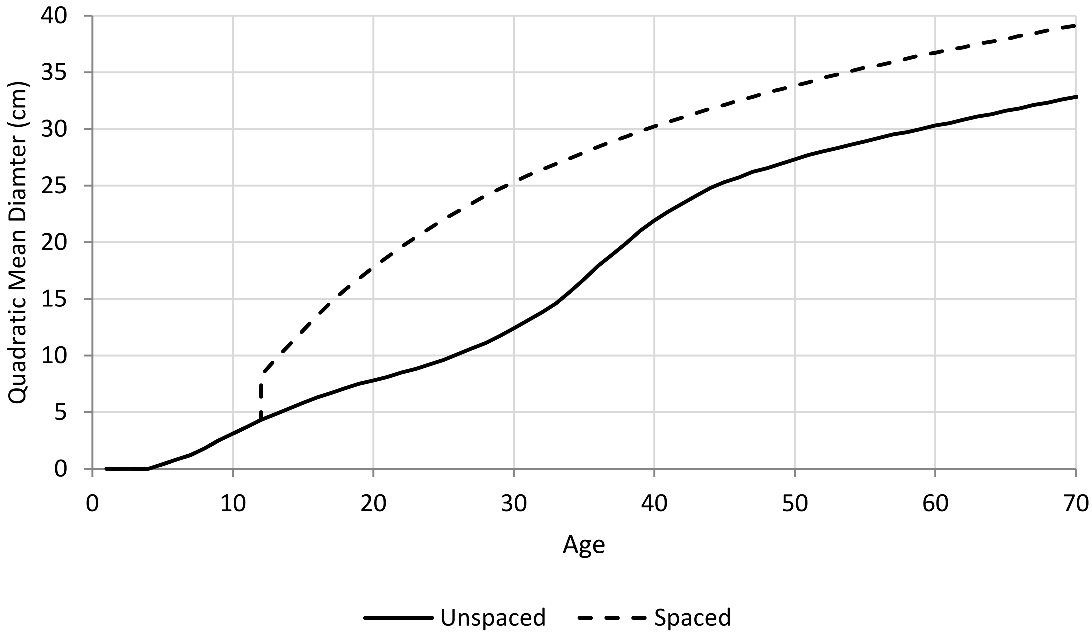

Figure 3. Quadratic mean diameter versus age for spaced and unspaced stands. Fd SI 31, 1000 Fd planted, 5000 Hw ingress. Spacing to 650 trees/ha at age 12.

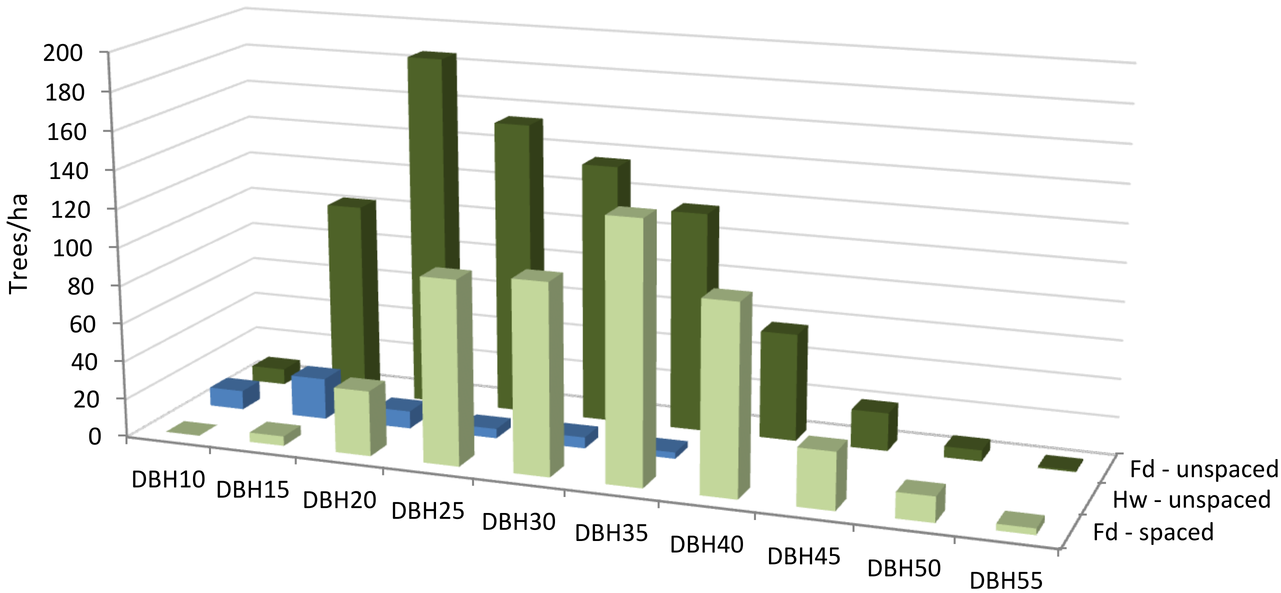

Figure 4. Diameter distributions for spaced and unspaced stands at age 50. Fd SI 31, 1000 Fd planted, 5000 Hw ingress. Spacing to 650 trees/ha at age 12.

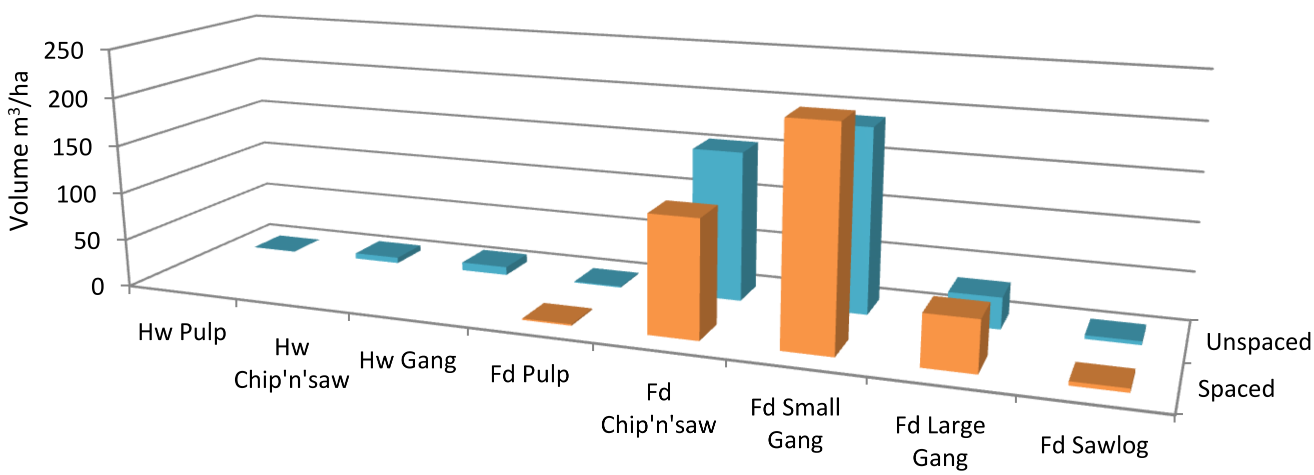

Figure 5. Log distributions for spaced and unspaced stands at age 50. Fd SI 31, 1000 Fd planted, 5000 Hw ingress. Spacing to 650 trees/ha at age 12.

6.2.5 STAND LEVEL FINANCIAL ANALYSIS RESULTS

When all cost and revenue assumptions are the same for both spaced and unspaced stands, none of the spacing treatments simulated across the range of stand types meets the requirement of a 2% return on investment.

In order for spacing to meet the 2% return on investment criteria, the harvest costs in the spaced stand must be reduced relative to the harvest costs in the unspaced stand. This required reduction in harvest cost is dependent on the site productivity (site index), the unspaced stand density and the juvenile spacing cost. As site productivity increases the required lowering of harvest costs decreases. As the unspaced stand density increases, the required reduction in harvest cost decreases. As juvenile spacing costs increase, the required lowering of harvest costs increases. For example, on site index 28, with less than 7,000 naturals/ha, the harvest costs for the unspaced stand had to be raised to \$55/m^3 and reduced to \$45/m^3 in the spaced stand in order for the 2% return on investment criteria to be met, and this was only possible when spacing costs were \$1500/ha. In comparison, on site index 34, only a \$5/m^3 difference in harvest cost was required (\$50/m^3 versus \$55/m^3) with a \$2000/ha spacing cost when there were 7000 naturals/ha.

The other key finding from the sensitivity analysis was the harvest age at which the juvenile spacing treatment provides a 2% return on investment. In many cases the required harvest age is older than spaced stands are currently being harvested at. If harvested too soon, the stand level benefits are not achieved and therefore to be justified the spaced stands must provide a forest level benefit.

One example of the above findings is demonstrated in Figure 6 for Fd site index 31, 1000 Fd planted and 5000 Hw naturals. Additional graphs for other site indices and stand densities are included in Appendix IV. These show similar trends to the graphs presented here. Planting costs and log values were kept constant at the base case values. The solid black line represents the site value versus harvest age for the unspaced stand assuming a harvest cost of \$55/m^3. The green, blue and red lines are for spacing to 650 sph with different combinations of spacing and harvest costs. The spacing treatment provides the 2% return on investment when the green, blue or red lines are equal to or above the black unspaced line. The green lines are for \$45/m^3 harvest cost, the blue for \$50/m^3 and the red for \$55/m^3. Note that all the red lines (\$55/m^3 harvest cost) are below the black line for the unspaced stand. When the harvest costs are the same in the spaced and unspaced stands, the 2% return on investment is not reached. When the harvest costs are reduced (green and blue lines) the harvest age at which the spacing treatment provides the 2% return varies with the juvenile spacing cost. The best case scenario for the juvenile spacing treatment is \$1500/ha spacing cost and a \$10/m^3 reduction in harvest cost from \$55 to \$45/m^3. In this case the 2% return on investment is met at age 33 (where the green short dashed line crosses the black line). In contrast if the juvenile spacing treatment remains at \$1500/ha, but the reduction in harvest cost is only from \$55 to \$50/m^3 then the 2% return on investment is not met until age 49 (where the blue short dashed line crosses the black line). Furthermore, if the juvenile spacing cost rises to \$1750/ha, then a reduction in harvest costs from \$55 to \$50/m^3 is not sufficient to provide the 2% return on investment.

All of the above demonstrates that the stand level justification for juvenile spacing is very sensitive to differences in future harvest costs between spaced and unspaced stands. In addition, although a reduction in harvest cost may result in a 2% return; this may be predicated on the spaced stand being harvested at an older age than is current operational practice. The required reduction in harvest cost is in turn a function of the juvenile spacing cost. The higher the spacing cost, the higher the required reduction in harvest cost. This all adds up to juvenile spacing being a risky investment at the stand level to provide a minimal 2% return. Typically risk in investment is dealt with by requiring a higher rate of return. Raising the required rate of return quickly negates most juvenile spacing treatments as viable investments at the stand level. This is demonstrated in Figure 7 which provides the identical information as Figure 6 with the exception of the discount rate being raised from 2% to 4%.

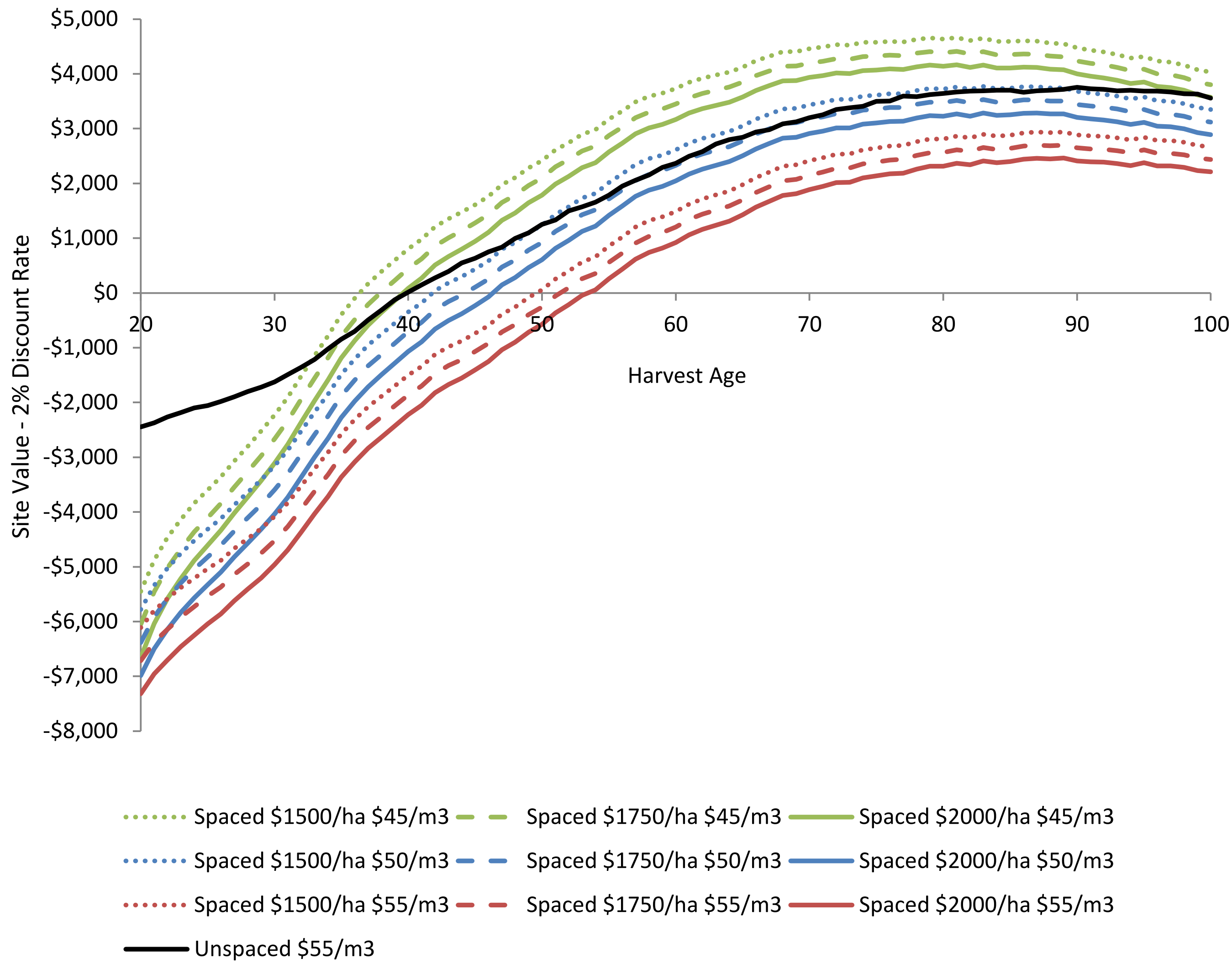

Figure 6. Site values (2% discount rate) versus age for Fd SI 31, 1000 Fd planted, 5000 Hw naturals with and without spacing to 650 sph for a range of spacing and harvest costs. The unspaced stand curve is based on a harvest cost of $55/m^3$.

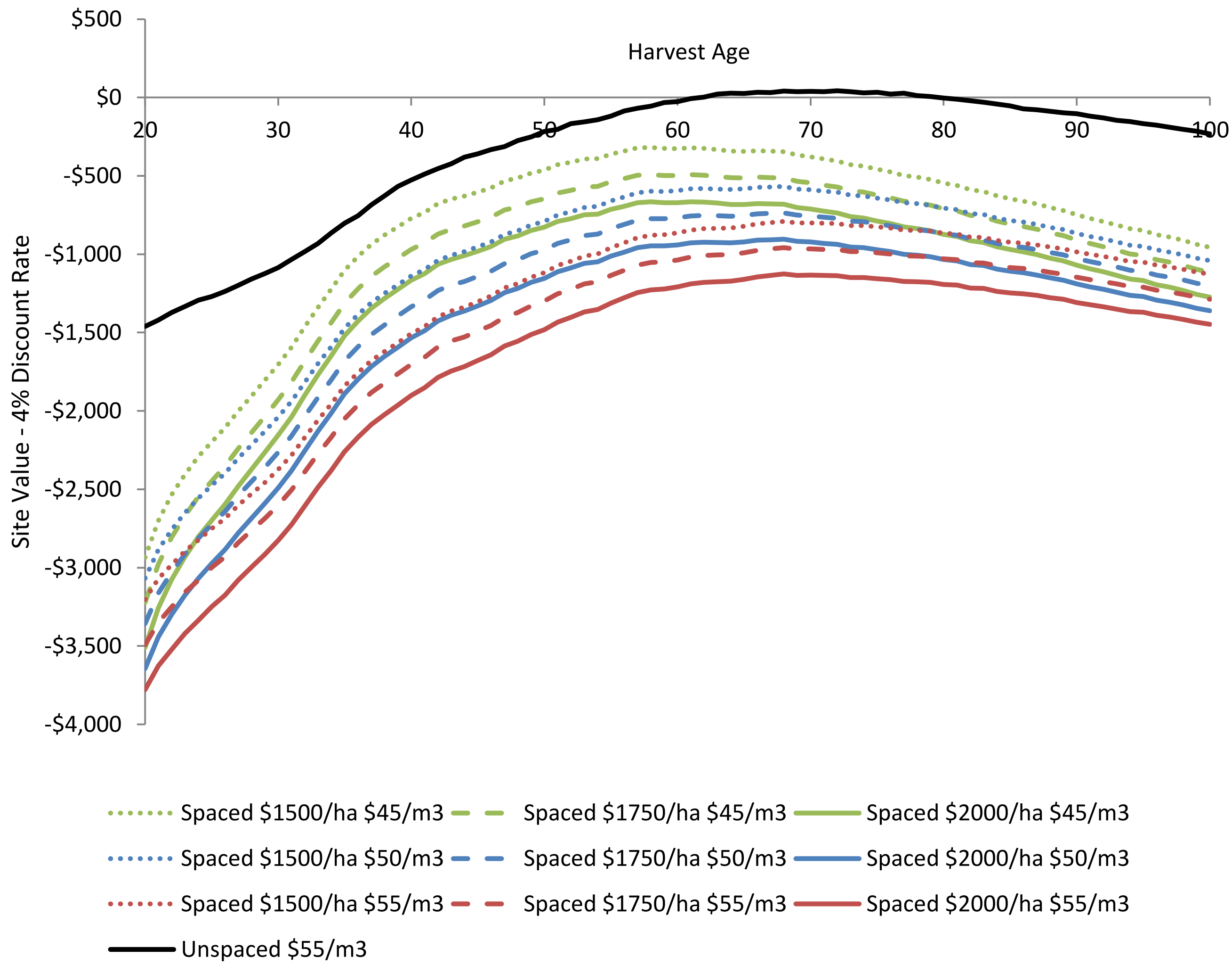

Figure 7. Site values (4% discount rate) versus age for Fd SI 31, 1000 Fd planted, 5000 Hw naturals with and without spacing to 650 sph for a range of spacing and harvest costs. The unspaced stand curve is based on a harvest cost of $55/m^3$.

6.3 WESTERN HEMLOCK AND AMABILIS FIR

6.3.1 TASS II SIMULATIONS

The matrix of TASS II runs done for Hw and Amabilis fir (Ba) are summarized in Table 7. All spacing was simulated as spacing from below with the objective of leaving well distributed trees. Example images from the TASS II simulations are shown in Figure 8 for 9,000 total trees on Hw site index 27 with and without spacing to 1000 sph at age 16 (top height 7 m).

Table 7. TASS II run matrix for Hw Ba mixtures.

Variable	Levels	# of Levels
Species Mix	Hw 60% Ba 40% (initial proportions)	1
Hw Site Index	18, 21, 24, 27, 30 m	5
Ba Site Index	15.8, 18.7, 21.7, 24.6, 27.6 m (from Hw-Ba SI conversion equation)	
Regen	Total trees of 6,000, 9,000 and 12,000	3
Planted	All runs had 1200 planted, 720 Hw and 480 Ba	
Ingress	4,800, 7,8000, 10,800 naturals (60/40 Hw/Ba) random spatial distribution	
Spacing	None, leave 850 sph, leave 1000 sph	3
Spacing age	At Hw top height of 5 and 7 m	2
OAFs	OAF1 = 0.85, OAF2 = 0.95	1
Total Runs		75

6.3.2 BUCKING SIMULATION

The industrial sorts summarized in Table 8 were used to guide the bucking simulation. Each tree was bucked between a 30 cm stump and a 10 cm top diameter to generate the optimum value using the average log value.

Table 8. Hw/Ba industrial log sorts for northern BC.

Sort	Min Top (cm)	Length (m)	Base Value	Steep Value
Sawlog	38	13	$70.00	$90.00
Sawlog	38	11	$70.00	$90.00
Sawlog	38	8	$70.00	$90.00
Gang	20	13	$60.00	$75.00
Gang	20	11	$60.00	$75.00
Gang	20	8	$60.00	$75.00
Chip'n'Saw	15	13	$50.00	$55.00
Chip'n'Saw	15	11	$50.00	$55.00
Chip'n'Saw	15	8	$50.00	$55.00
Chip'n'Saw	15	6.3	$50.00	$55.00
Chip'n'Saw	15	5.1	$50.00	$55.00
Pulp	12.5	5	$30.00	$25.00

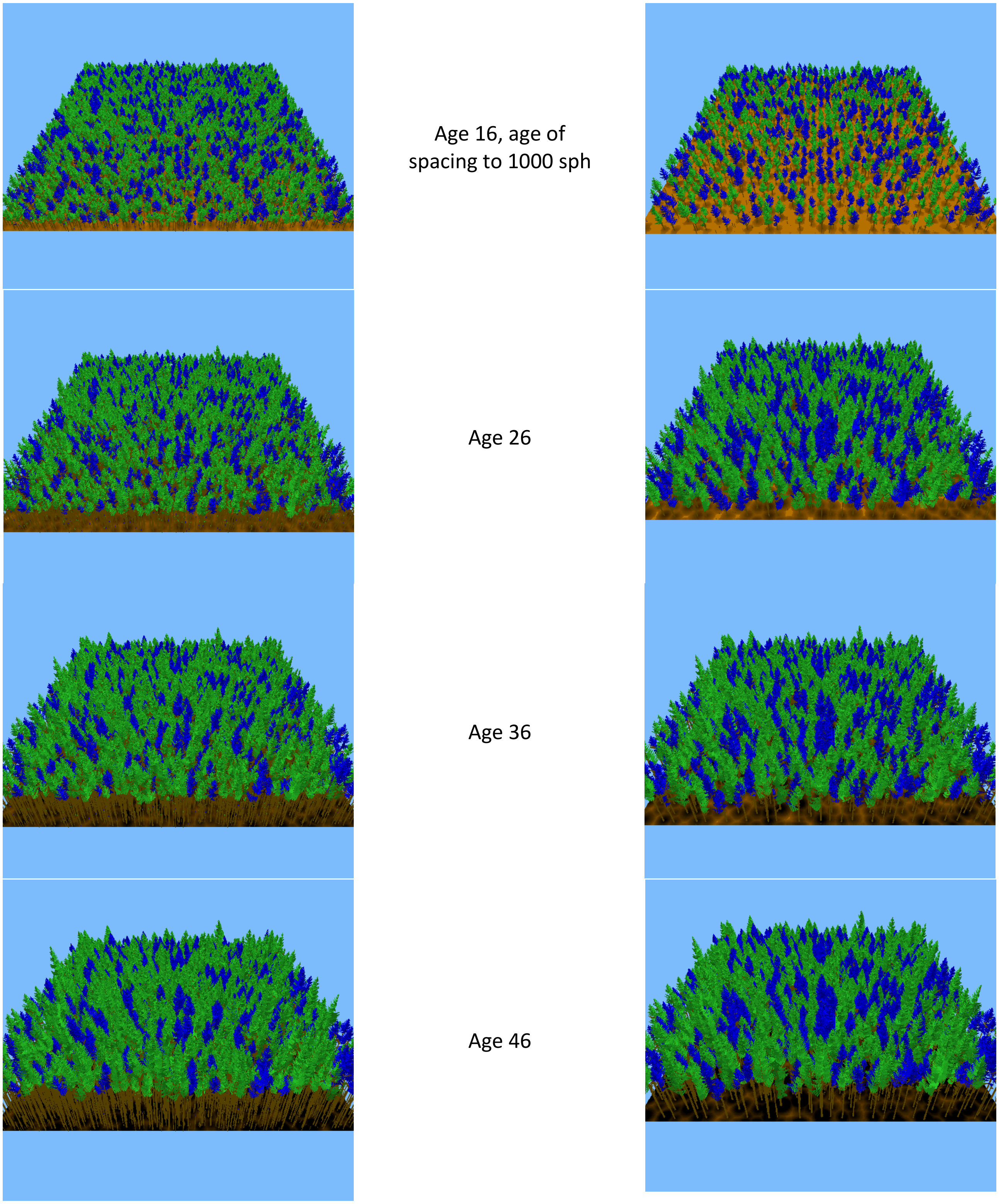

Figure 8. TASS II images of 5,400 Hw (green) and 3,600 Ba (blue), Hw SI 27, unspaced (left) and spaced to 1000 sph (right).

6.3.3 REVENUE AND COST ASSUMPTIONS

The FFT prescribed discount rate of 2% was used to evaluate spacing treatments. The same planting costs per tree (Table 6) as used for the Fd analysis were used. These were kept constant in comparisons between spaced and unspaced runs, so these costs have no impact on the ranking of treatments. Average, low and high (all found) juvenile spacing costs of $2,100, $1,800 and $2,400 per hectare used. Harvest costs are for ground-based tree to truck costs with variations reflecting differences in access and potential impacts of juvenile spacing on harvest costs. It should be noted that several foresters interviewed indicated a drop in harvest costs between old growth and second growth harvesting, but there is little to no experience in the northwest to predict differences in harvesting costs between spaced and unspaced second growth.

Pulp logs were output from the bucking simulation but were excluded from the revenue as well as the log volume used to estimate total harvest costs (cost/m^3 X log volume (m^3)). This is done to reflect the fact that there is no market for pulp logs in the northwest and that harvest costs are based on delivered wood.

Log values were varied according the values in Table 8. The base case values represent current domestic prices. The steep set of values was generated for sensitivity analyses.

6.3.4 GROWTH AND YIELD RESULTS

An example of the common pattern of stand development in terms of volume between an unspaced and spaced stand is shown in Figure 9. The example presented is for Hw site index 24, 1200 trees/ha planted plus 4,800 naturals. Spacing is to 850 trees/ha at age 19. Whether or not the spaced or unspaced stand has the most volume at any point in time is dependent on the volume definition (minimum diameter limit). The unspaced stand has more total volume (no diameter limit) until approximately age 90 at which point the spaced stand starts to have slightly more total volume. In contrast the spaced stand always has more volume above a 27.5 or 37.5 cm diameter limit. These different volume versus age curves are also useful for demonstrating when the stands start to accumulate volume over a defined diameter. For example, it is not until age 43 that the spaced stand has 100 m^3/ha in stems 27.5 cm dbh and larger, and not until age 50 that the same is true for the unspaced stand.

Log volumes (m^3/ha) by sort and age for a spaced and unspaced stand are provided as an example in Table 9. The simulated stands chosen for this example are the same as used in Figure 9. (Hw site index 24, 1200 trees/ha planted plus 4,800 naturals. The spaced stand was spaced at age 19 to 850 stems/ha.) The differences between the two stands at each age are also provided. For example, at age 45, the spaced stand has 32 m^3/ha more volume in gang logs and 12 m^3/ha less in chip'n'saw logs.

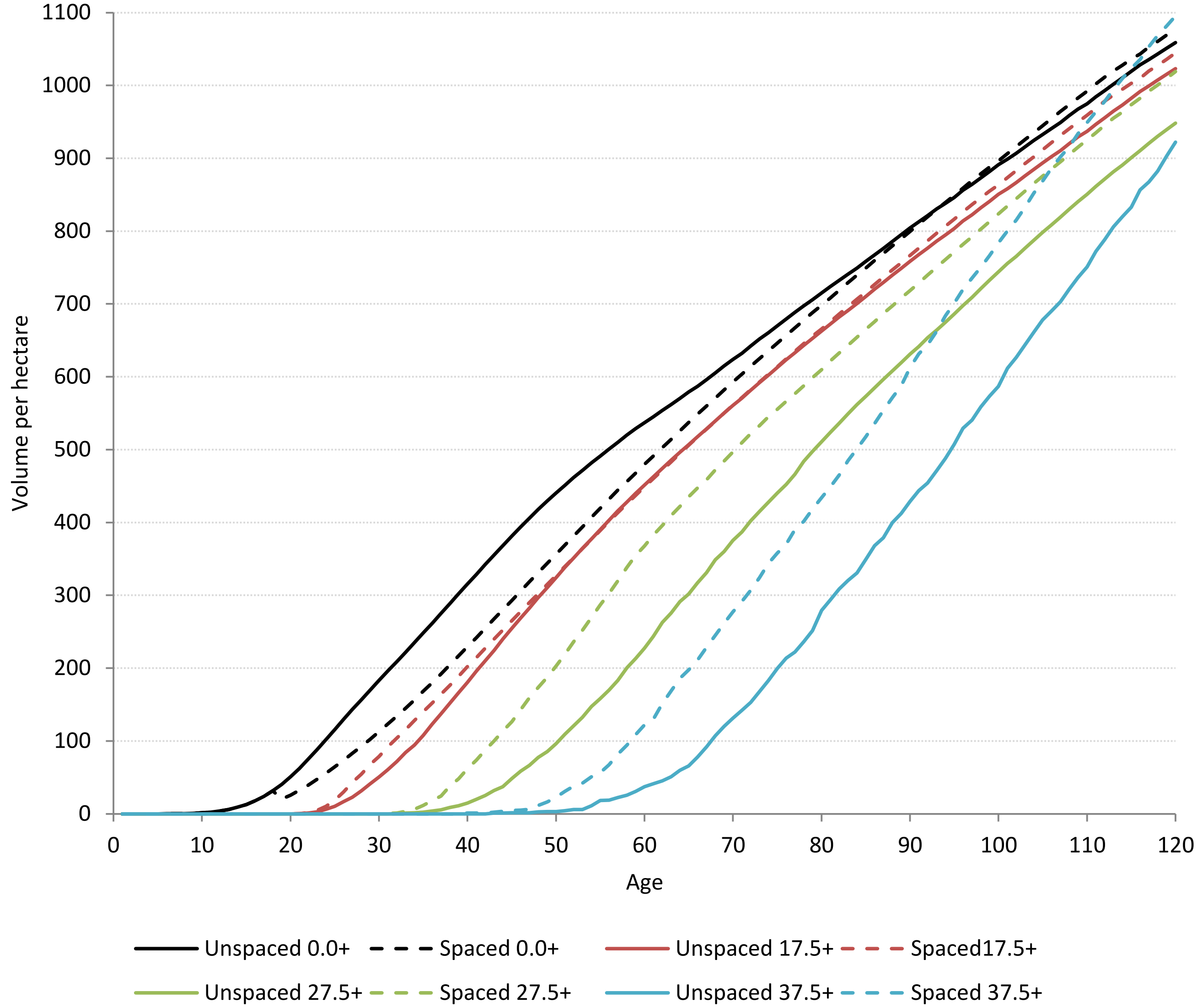

Figure 9. Volume/ha at different merchantable limits for a spaced and unspaced stand. Both stands are Hw site index 24, 1,200 trees/ha planted, 4,800 naturals with a species composition of 60% Hw, 40% Ba. The spaced stand was spaced at age 19 to 850 stems/ha.

Table 9. Log volumes (m^3/ha) by sort and stand age for an unspaced and spaced stand. Both stands are Hw site index 24, 1,200 trees/ha planted, 4,800 naturals with a species composition of 60% Hw, 40% Ba. The spaced stand was spaced at age 19 to 850 stems/ha.

		Stand Age							
	Sort	**45**	**50**	**55**	**60**	**65**	**70**	**75**	**80**
Unspaced	**Sawlog**	0	0	1	2	5	10	24	44
	Gang	52	108	169	234	297	348	394	429
	Chip'n'saw	146	150	154	146	138	137	127	123
	Pulp	41	46	42	43	39	36	37	36
	Total	239	304	366	425	478	530	582	632
	Total no pulp	198	258	324	382	439	495	546	596
	Sawlog + Gang	52	108	170	236	301	358	418	473
Spaced	**Sawlog**	0	0	3	5	19	35	60	90
	Gang	84	157	229	293	342	384	413	439
	Chip'n'saw	134	119	103	97	92	88	87	83
	Pulp	18	25	30	28	29	30	29	29
	Total	237	301	365	424	481	536	590	641
	Total no pulp	218	276	335	395	452	507	560	613
	Sawlog + Gang	84	157	231	298	360	418	473	529
Difference (spaced minus Unspaced)	**Sawlog**	0	0	2	3	14	25	36	47
	Gang	32	49	60	59	45	36	19	10
	Chip'n'saw	-12	-31	-51	-49	-46	-48	-40	-40
	Pulp	-23	-21	-12	-14	-11	-6	-7	-7
	Total	-3	-3	-1	-1	3	6	7	10
	Total no pulp	20	17	11	13	13	12	15	17
	Sawlog + Gang	32	49	62	62	59	60	55	57

The quadratic mean diameter versus age for the same two stands is shown in Figure 10. Using this simple statistic to determine harvest ages is clearly misleading when compared to the information provided by the complete stand and stock tables, the volume above defined diameter limits or expected log distributions.

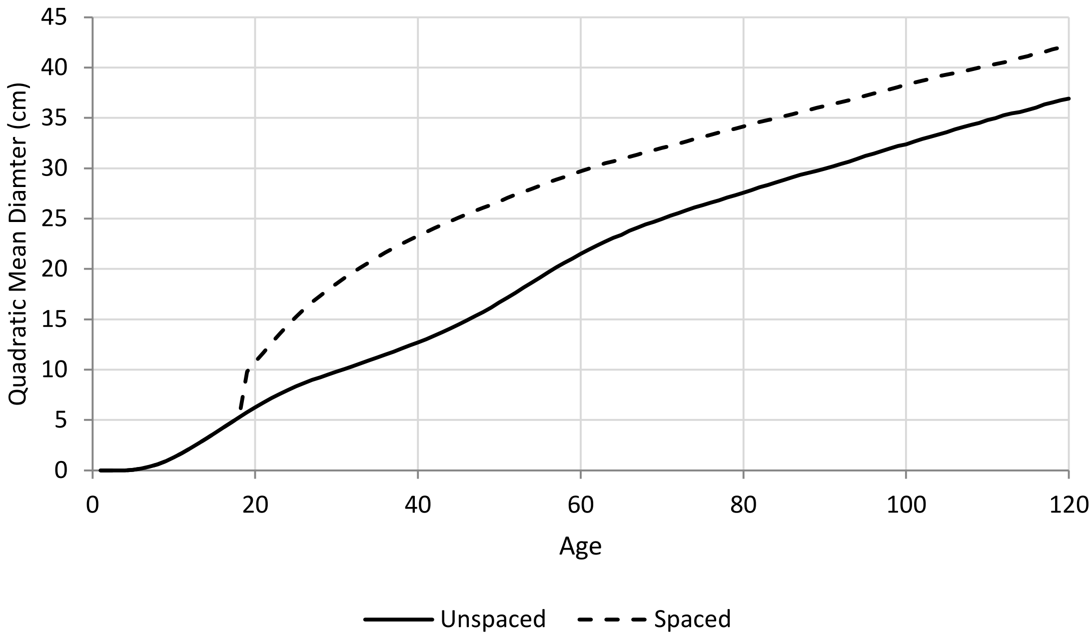

Figure 10. Quadratic mean diameter versus age for spaced and unspaced stands. Both stands are Hw site index 24, 1,200 trees/ha planted, 4,800 naturals with a species composition of 60% Hw, 40% Ba. The spaced stand was spaced at age 19 to 850 stems/ha.

The minimum harvest criteria from the most recent Kalum Timber Supply Review[9] were:

- 19.5 m top height
- 250 m^3/ha volume (17.5 cm dbh limit)
- Quadratic mean diameter 25 cm

To test these minimum harvest age criteria they were used to determine a minimum harvest age for all 75 TASS Hw/Ba simulations. In all cases, the limiting factor was quadratic mean diameter. For the site index 24 simulations the spaced stands reached the minimum harvest age 22 – 27 years sooner than the unspaced stands. An examination of the stand characteristics when the minimum quadratic mean diameter is met demonstrates the problem with using this metric to define a minimum harvest age. Consider the spaced and unspaced stands shown in Figure 9 and Figure 10 (Hw SI 24, 6000 initial stems/ha, spaced to 850 stems/ha at age 19). The stand characteristics of each stand when they meet the minimum harvest age are summarized in Table 10.

[9] Kalum TSA TSR updated data package 2010. Accessed at https://www.for.gov.bc.ca/hts/tsa/tsa10/tsr2009/10ts10dp_update.pdf

Table 10. Characteristics of a spaced and unspaced stand when they meet minimum harvest criteria.

Variable	Spaced	Unspaced	Difference
Age (years)	45	71	26
Top Height (m)	21.0	30.2	9.2
DBHq (cm)	25	25	0
Volume 17.5 cm dbh + (m^3/ha)	319	696	377
Sawlog volume (m^3/ha)	0	17	17
Gang log volume (m^3/ha)	84	353	269
Chip'n'saw volume (m^3/ha)	134	135	1

Compared to the spaced stand when it reaches the minimum harvest criteria, the unspaced stand has more than double the merchantable volume and 4.4 times the volume of sawlogs and gang logs when it finally reaches the constraining minimum harvest criteria (minimum quadratic mean diameter). The use of quadratic mean diameter as a minimum harvest criterion clearly sets a drastically different hurdle for the two stands and leads to misleading conclusions about the value of spacing at the stand and forest level. Growth and yield analysts recommend that mean diameter is never used as a determinant of minimum harvest age either alone or in combination with other stand statistics. The rationale for this recommendation is to avoid the illusion created by the "chainsaw effect" whereby mean diameter is increased immediately after thinning that preferentially removes the smaller trees in the stand. The example above demonstrates the power of this illusion. This is explained in detail in the Ministry's 1999 document "Guidelines for developing stand density management regimes".

6.3.5 STAND LEVEL FINANCIAL ANALYSIS RESULTS

When all cost and revenue assumptions are the same for both spaced and unspaced stands, none of the spacing treatments simulated across the range of stand types and spacing costs meets the requirement of a 2% return on investment. This includes using the steep log values for both spaced and unspaced stands.

In order for spacing to meet the 2% return on investment, the harvest costs in the spaced stand must be reduced relative to the harvest costs in the unspaced stand. This required reduction is dependent on the site productivity (site index) and the juvenile spacing cost. As site productivity increases the required lowering of harvest cost decreases. As juvenile spacing costs increase, the required lower of harvest costs increases. For example on Hw site index 24 a \$10/m^3 difference in harvest cost results in spacing meeting the 2% return on investment criteria, however a \$5/m^3 decrease in cost does not. The required reduction in harvest cost is also slightly impacted by the unspaced stand density, but not to the same degree as in the Fd/Hw simulations. This results primarily from pulp logs being excluded (i.e., assumed to be left on site) in the analysis (Section 6.3.3).

Of the four spacing treatments simulated (spacing to 850 and 1000 stems/ha at top heights of 4 and 7 m) the later spacing (top height 7 m) to the lower density (850) consistently produced a slightly better site value.

One example of the above findings is demonstrated in Figure 11 for Hw site index 24 with an initial density of 6,000 stem/ha and spacing at age 19 (top height 7 m) to 850 stems/ha (other combinations of site indices, initial densities and post spacing densities showed similar trends). Planting costs and log values were kept constant at the base case values. The unspaced stand site values are calculated with \$55/m^3 harvest costs and shown in the solid black line. For the spaced stand, site values for nine combinations of juvenile spacing and harvest costs are shown. All site values are calculated with a 2% discount rate. When any of the site values for the spaced stand cross and go above the values (black line) for the unspaced stand, a 2% return on investment is achieved. As can be seen in this example, this only happens for the green lines (\$45/m^3 harvest cost).

The above demonstrates that meeting a 2% return on investment for spacing is predicated on significant reductions in harvest costs compared to the unspaced second growth stands.

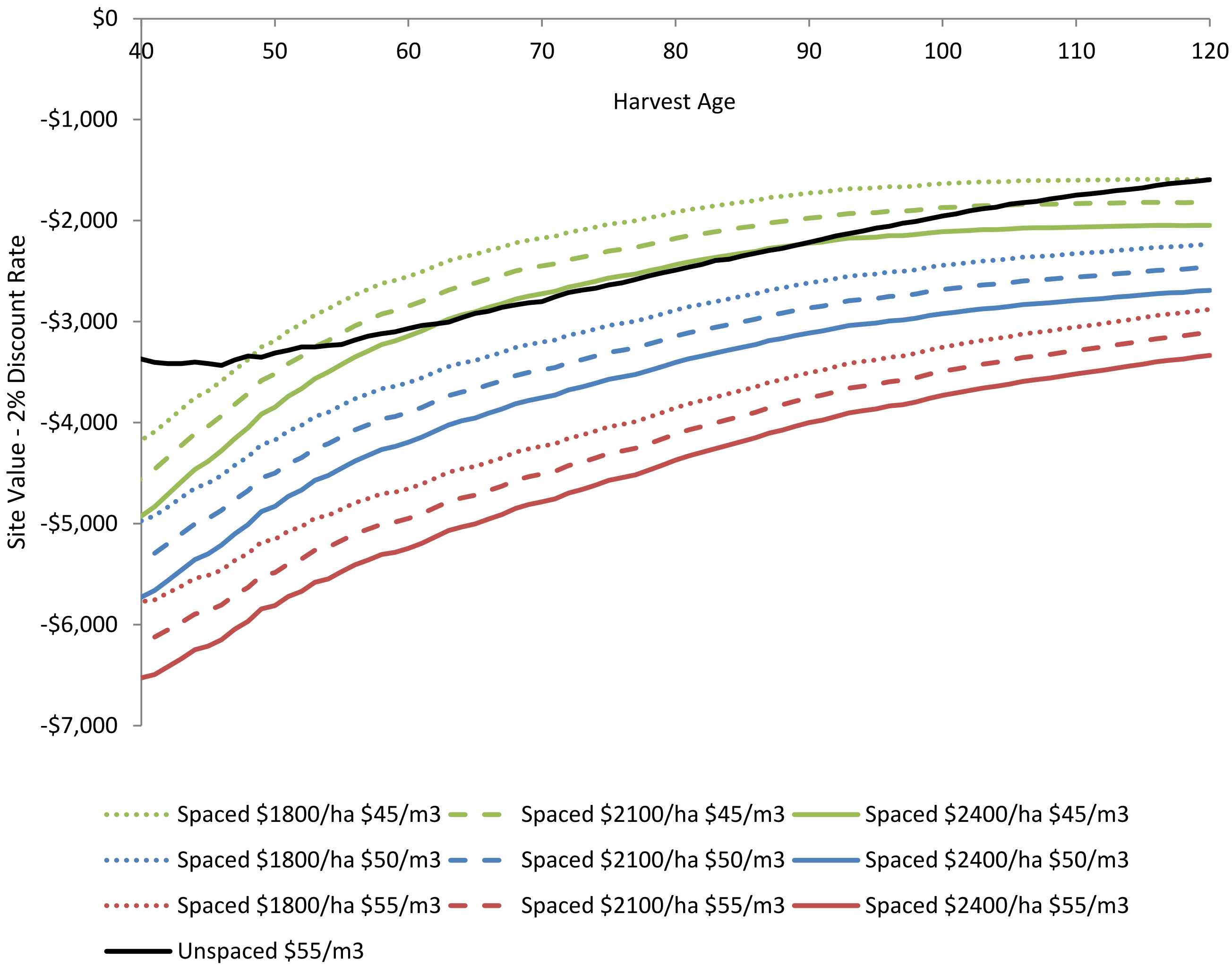

Figure 11. Site values (2% discount rate) versus age for stands established with 6000 trees/ha on Hw site index 24. The unspaced stand is shown in black at a harvest cost of \$55/m3. The spaced stand (spacing to 850 stems/ha at age 19) is shown for combinations of spacing and harvest costs.

6.4 RED ALDER

6.4.1 TASS II SIMULATIONS

The matrix of TASS II runs done for Dr is summarized in Table 11. All spacing was simulated as spacing from below with the objective of leaving well distributed trees. Stands planted with 1200 trees were only spaced to 700 (not 700 and 1000). Images from the TASS II simulations for 1,600 planted on SI 36 are shown with and without spacing to 700 sph at age 9 in Figure 12.

Table 11. TASS II run matrix for Dr stands.

Variable	Levels	# of Levels
Species	Dr	1
Dr Site Index	32, 34, 36, 38 m	4
Planted	1,200, 1,600, 2,000	3
Spacing	None, leave 1000 sph, leave 700 sph	3
Spacing age	At age 10 for SI 32 and 34, and age 9 for SI 36 and 38	1
OAFs	OAF1 = 0.85, OAF2 = 0.95	1
Total Runs		32

6.4.2 BUCKING SIMULATION

Industrial sorts based on all combinations of the minimum top diameters and log lengths summarized in Table 12 were used to guide the bucking simulation.[10] Each tree was bucked between a 30 cm stump and a 10 cm top diameter to generate the optimum value using the base values. Values were based on top diameters (Table 12).

Table 12. Dr industrial log sorts.

Lengths (m)
5.1
5.7
6.3
7.6
8.3
8.9
9.5
10.8
12.0
13.3
13.9
14.6

Min Tops (cm)	Base Values	Flat Values
15.2	$35	$60
17.8	$45	$65
20.3	$65	$70
25.4	$110	$75
30.5	$125	$85

[10] Brian Kyle of Northwest Hardwoods provided the information used to develop these sorts and prices for the TASS II simulations.

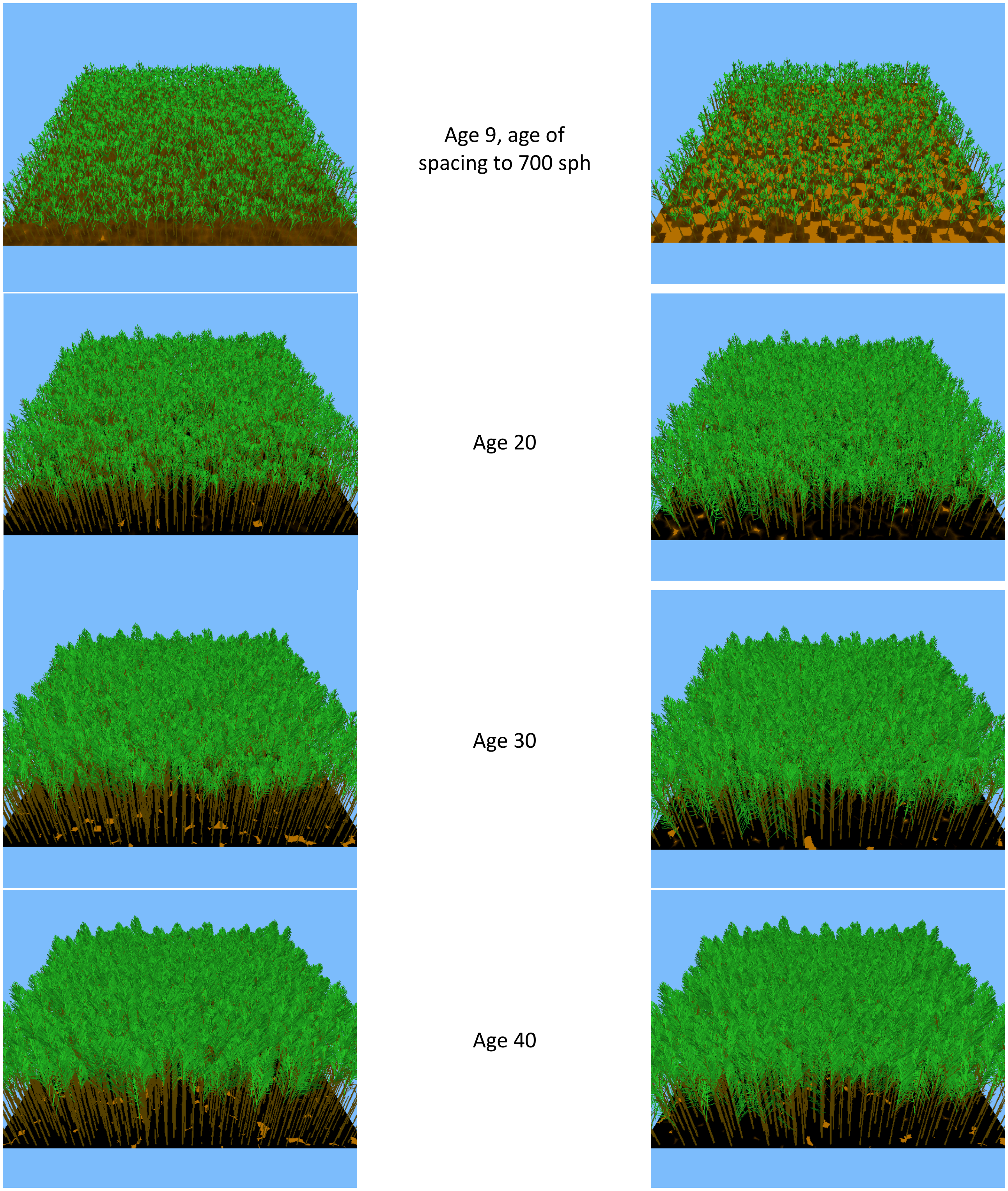

Figure 12. TASS II images of 1,600 Dr planted, SI 36, unspaced (left) and spaced to 700 sph (right).

6.4.3 REVENUE AND COST ASSUMPTIONS

The FFT prescribed discount rate of 2% was used to evaluate spacing treatments. Planting costs per tree (Table 13) varied by density. Average, low and high (all found[11]) juvenile spacing costs of $1,800, $1,200, and $2,400 per hectare were used. The cost variation primarily reflects differences in access and slope. Harvest costs were set at $50/m^3 and varied between $45 and $55/m^3. Harvest costs are for ground-based tree to truck costs with variations reflecting differences in access. Log values were varied according to the values in Table 12. Base values were provided by Brian Kyle of Northwest Hardwoods. The flat values were used in sensitivity analysis to test what happens when there is less of a premium for larger logs.

Table 13. Dr planting costs.

Planting Density	Cost per tree Average	Low	High
1,200	$0.76	$0.66	$0.86
1,600	$0.74	$0.64	$0.84
2,000	$0.72	$0.62	$0.82

6.4.4 GROWTH AND YIELD RESULTS

Examples of volume versus age for site index 36 stands with and without spacing are presented in Figure 13 and Figure 14 for merchantable limits of 12.5 cm and 22.5 cm dbh respectively. Note that with a merchantable limit of 12.5 cm dbh the spaced stands have less volume than the unspaced until approximately age 30. With a 22.5 cm dbh limit the spaced stands have more volume from age 15 onwards. The percentage of the merchantable volume (12.5 cm +) that is bucked into logs 5.1 m in length and longer is shown in Figure 15. Up until approximately age 35 a higher percentage of the merchantable volume in the spaced stands can be merchandised into logs. Example diameter and log distributions at age 30 are shown in Figure 16 and Figure 17. Again these demonstrate that the unspaced stand does have large trees and will produce some large logs, but the proportions are increased in the spaced stand.

[11] All found costs include prescription, treatment, survey and overhead costs.

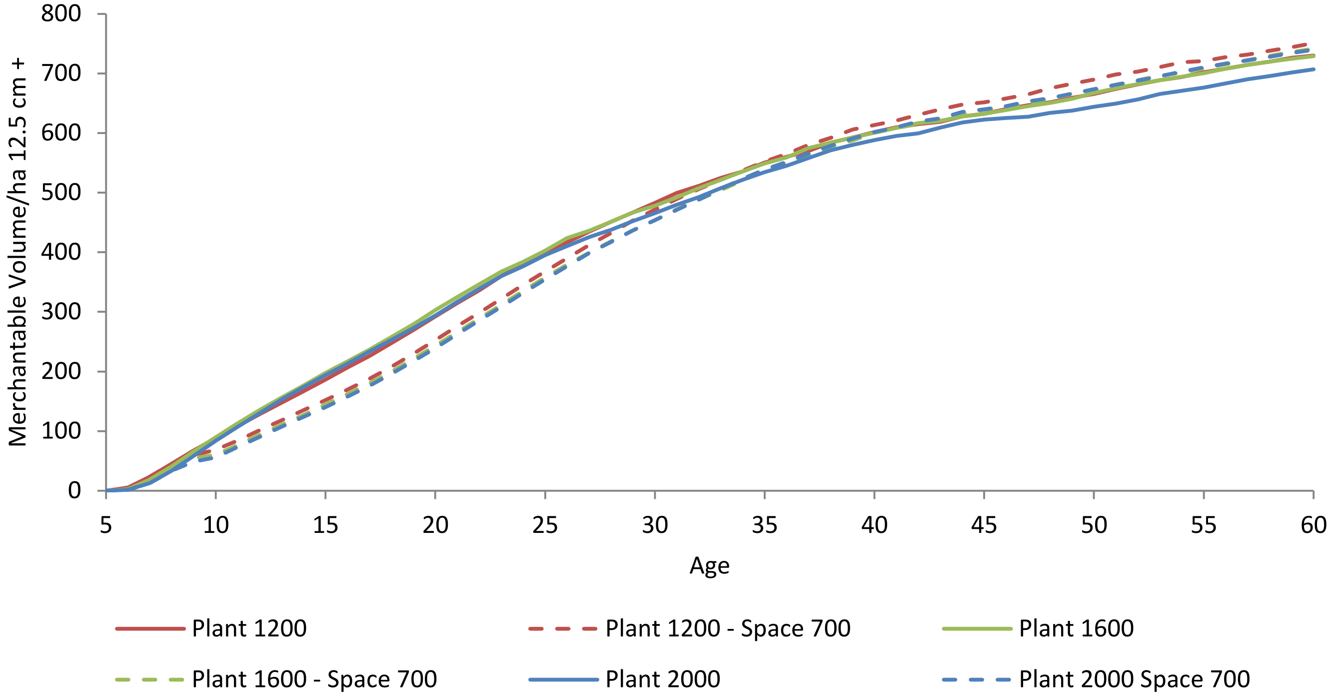

Figure 13. Red alder SI 36 merchantable volume (12.5 cm dbh +) versus age for a range of planting densities with and without spacing.

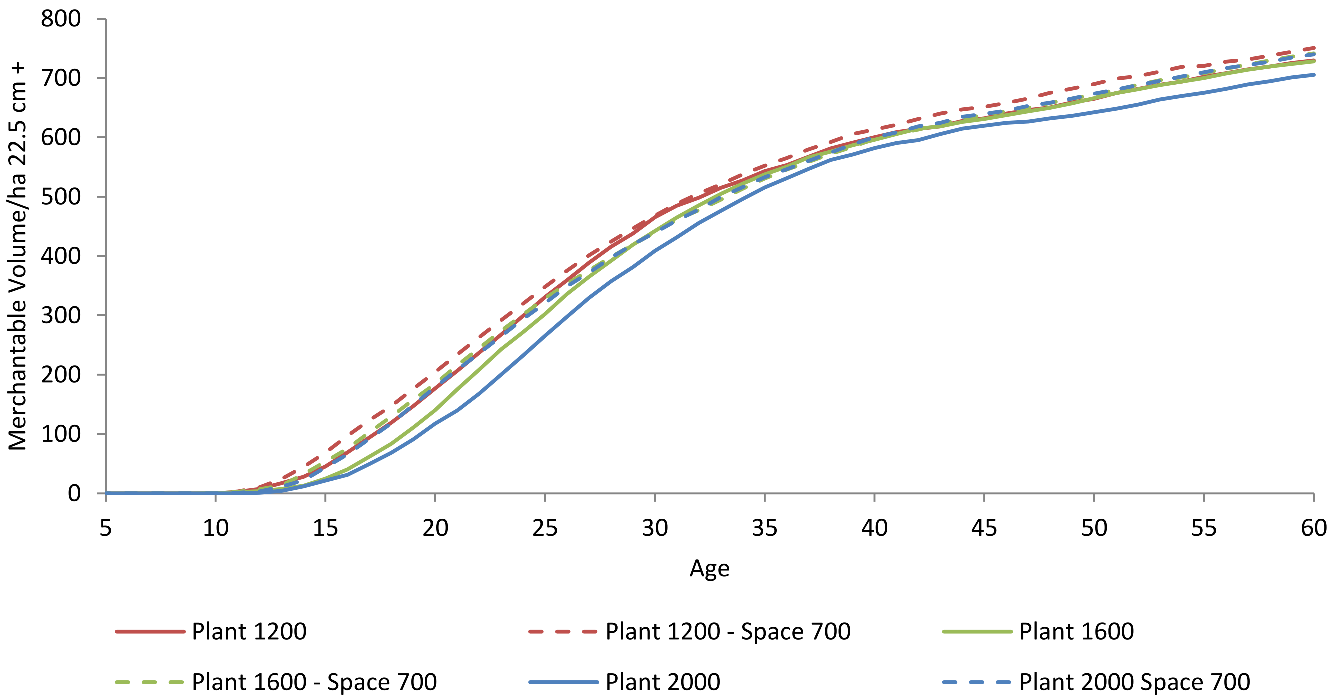

Figure 14. Red alder SI 36 merchantable volume (22.5 cm dbh +) versus age for a range of planting densities with and without spacing.

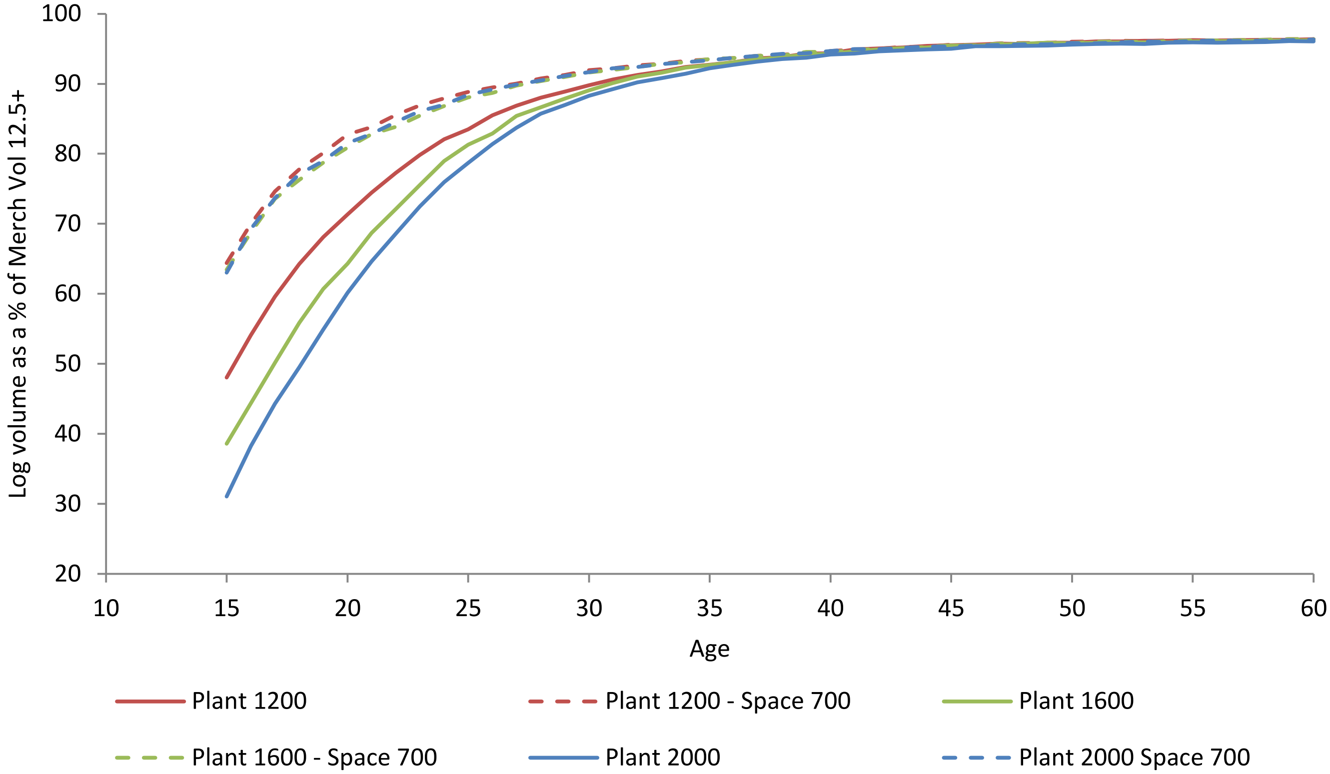

Figure 15. Red alder SI 36 total log volume as a percentage of merchantable volume (12.5 cm dbh +) for a range planting densities with and without spacing.

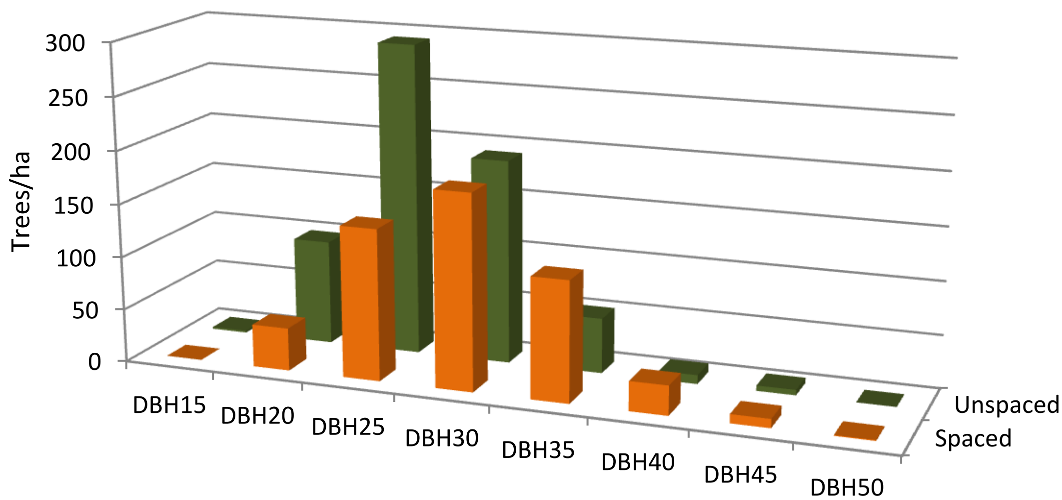

Figure 16. Diameter distributions for spaced and unspaced stands at age 30. Dr SI 36, 1600 planted. Spacing to 700 trees/ha at age 9.

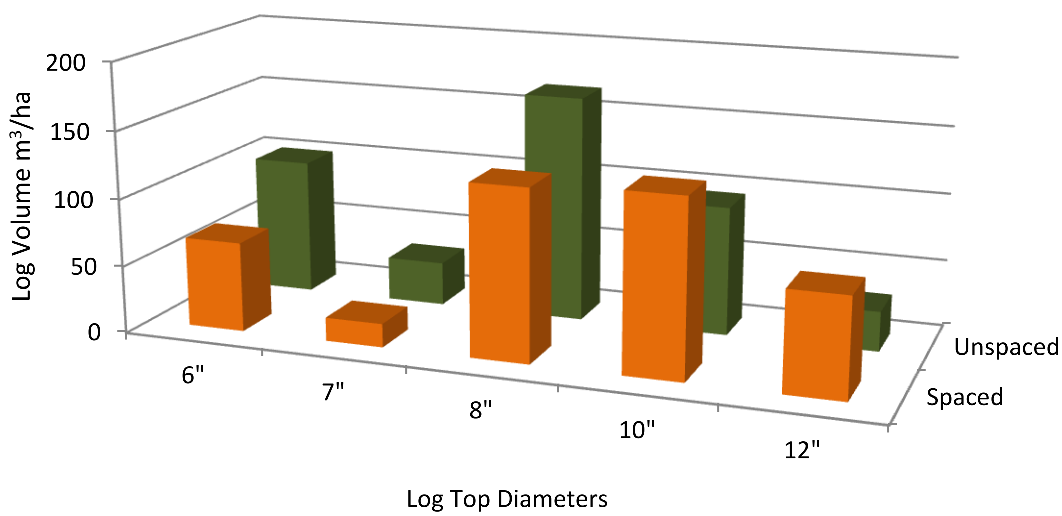

Figure 17. Log distributions for spaced and unspaced stands at age 30. Dr SI 36, 1600 planted. Spacing to 700 trees/ha at age 9.

6.4.5 STAND LEVEL FINANCIAL ANALYSIS RESULTS

Using the base log values and average costs juvenile spacing of Dr to 700 trees/ha provides a 2% return in all cases tested. Increasing the juvenile spacing costs to $2400/ha negates the 2% return on the lower site indices (32 and 34), but not on the higher site indices (36, 38). However these results are sensitive to assumptions about log values. If the flat set of log values are used then the 2% return is not met even on the high sites with the lowest spacing cost.

For each of the four site indices (32, 34, 36, 38), eight different treatments were simulated:

1. Plant 1200
2. Plant 1200, space to 700
3. Plant 1600
4. Plant 1600, space to 1000
5. Plant 1600, space to 700
6. Plant 2000
7. Plant 2000, space to 1000
8. Plant 2000, space to 700

In all cases spacing to 700 stems/ha provided a better return than spacing to 1000 stems/ha under the base case cost and revenue assumptions. The ranking of the eight treatments using the base case cost and values are summarized by site index in Table 14. As demonstrated in Figure 18 and Figure 19, these rankings are sensitive to log values.

Table 14. Ranking of treatment options by site index using base case costs and values.

	Site Index (m)			
Treatment	**32**	**34**	**36**	**38**
Plant 1200, space to 700	1	1	1	1
Plant 1600, space to 700	3	3	2	2
Plant 1200	2	2	3	3
Plant 2000 space to 700	4	4	4	4
Plant 1600	5	5	5	5
Plant 1600, space to 1000	6	6	6	6
Plant 2000, space to 1000	8	8	7	7
Plant 2000	7	7	8	8

The choice of planting density is highly sensitive to the assumed difference in log values resulting from quality differences across the planting densities. If the log values for stands planted with 2000 trees/ha are raised 5%, and the log values for those stands planted with 1200/ha are lowered 5%, relative to the base case, then the best overall option becomes planting 2000/ha and spacing to 700 (Table 15). The Hardwood management strategy states that "Red alder saw logs increase in value with diameter and proportion of clear wood with the highest values in appearance grades. Large branches are attributed to causing the greatest reduction in value of log grades." Clearly the ability to accurately forecast log quality and values resulting from various treatment regimes would help refine the treatment decision process.

Table 15. Ranking of treatment options by site index using base case costs and base values for 1600 planted. Log values for 2000 planted raised 5% over base and log values for 1200 planted lower 5%.

	Site Index (m)			
Treatment	**32**	**34**	**36**	**38**
Plant 2000, space to 700	1	1	1	1
Plant 1600, space to 700	2	2	2	2
Plant 2000 space to 1000	7	4	3	3
Plant 2000	6	6	4	4
Plant 1200, space to 700	3	3	5	5
Plant 1600	5	5	6	6
Plant 1600, space to 1000	8	8	8	7
Plant 1200	4	7	7	8

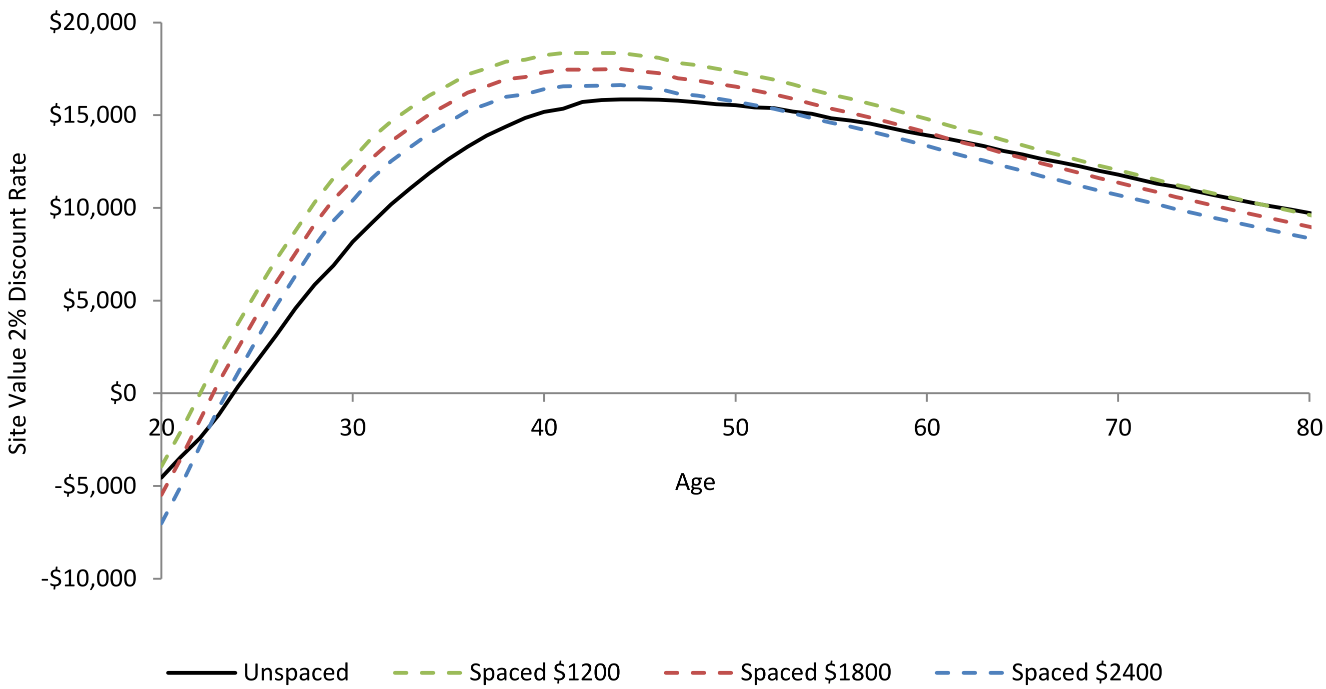

Figure 18. Site value versus age for Dr Site Index 36, planted with 1600 trees/ha and spaced to 700 trees/ha. Using *base log values* and a range juvenile spacing costs ($/ha).

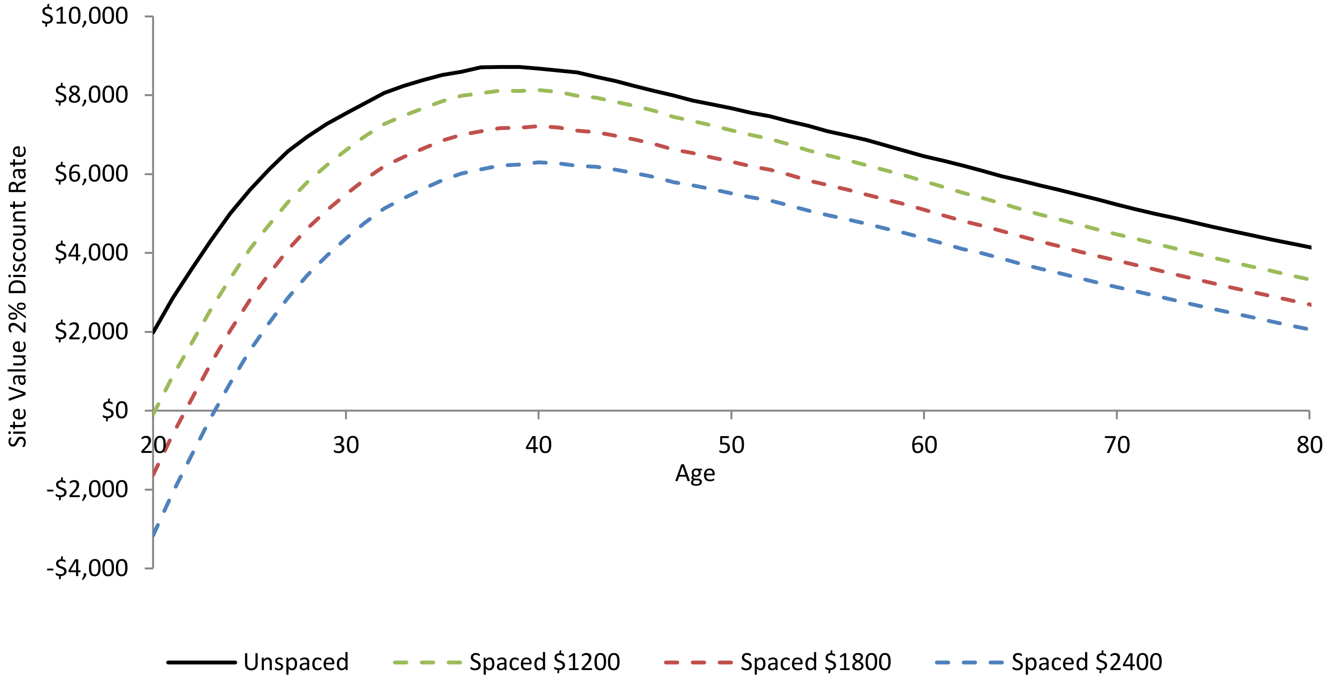

Figure 19. Site value versus age for Dr Site Index 36, planted with 1600 trees/ha and spaced to 700 trees/ha. Using *flat log values* and a range juvenile spacing costs ($/ha).

7.0 DISCUSSION

Juvenile spacing treatments carried out between 2010 and 2016 were generally consistent with treatment strategies in silviculture strategies and the FFT funding criteria in place at the time. However this consistency should be of limited comfort as many of the strategies were completed more than 10 years ago and/or did not include detailed stand and forest level analysis which would allow one to determine the viability of JS. In addition current FFT funding criteria for many types of JS are much different (especially relative to pre-JS densities) than were in effect when the majority of the prescriptions were developed. While it is difficult to be certain, it appears that many of the treated stands would not meet the current criteria. Feedback from several government staff interviewed for this project indicated that the supply of stands which would meet the current FFT funding criteria and the Cariboo Region criteria for stand selection in dry belt Fdi stands (Day et *al*. 2011) is very low.

Relative to strategic support for JS, it should be noted that many of the more recently completed silviculture strategies in the interior which, included JS as a recommended treatment, but listed it as a low priority relative to other preferred treatments.

Many prescriptions for JS stands were not attached to RESULTS and the pre-treatment stand data in the available prescriptions varied in quality. This made it difficult to fully assess if stand and forest level objectives were being met. Despite the large amount of data available in RESULTS, detailed assessment of the effectiveness and viability of JS requires access to the detailed pre-stand tending data and objectives stated in the prescriptions.

TASS II simulations of Dr spaced and unspaced stands combined with site value analysis demonstrated that juvenile spacing of Dr will provide a 2% return on investment in most cases. However these results are sensitive to the assumed differential in log prices and juvenile spacing costs. In addition the choice of Dr planting density prior to juvenile spacing is highly sensitive to the assumed differences in log values resulting from quality differences across the planting densities (assuming higher initial densities result in smaller branches and therefore better quality logs). It only requires a small increase in assumed quality and price to make planting 2000 stems/ha the preferred choice over 1200 or 1600 stems/ha.

TASS II simulations of Fd/Hw and Hw/Ba spaced and unspaced stands combined with site value analysis demonstrated that whether or not the spacing treatment provides a 2% return at the stand level is very sensitive to input assumptions, in particular, the assumed differences in harvest costs per m^3 between spaced and unspaced stands. When looking at the full distribution of logs produced in the spaced and unspaced stands the additional volume of larger logs is not sufficient on its own to justify the juvenile spacing costs. There must be an accompanying reduction in harvest cost in the spaced stand. This required reduction in harvest cost is dependent on both the site productivity (site index) and the juvenile spacing cost. As site productivity increases the required lowering of harvest costs decreases. As juvenile spacing costs increase, the required lowering of harvest costs increases.

Across the breadth of stand types being spaced there is very little recent data on differential harvest costs between spaced and unspaced second growth stands on the same sites in BC. Harvest methods, log values and utilization levels are continually changing and analysis should be based on current estimates with sensitivities done to address future un-certainty. Most people interviewed commented that the spaced second growth was cheaper to harvest than old growth, but couldn't comment on the differences in cost between spaced and unspaced second growth on similar sites. The opinions of the industry representatives with experience in second growth harvesting ranged from no difference to a $5/m^3 reduction in harvest cost between spaced and unspaced second growth. The take home message is that there are only opinions and there is very little current data for the stand types in question. This uncertainty must be acknowledged in any analyses of the investment decisions. In addition analysis should be based on the complete diameter distribution of the stand acknowledging the components that are expected to be recovered and the non-merchantable material.

The other key finding from the Fd/Hw and Hw/Ba sensitivity analyses was the harvest age at which the juvenile spacing treatment provides a 2% return on investment at the stand level with differential harvest costs. In many cases the required harvest age is older than spaced stands are currently being harvested at or targeted for harvest under the FFT strategy of making stands available for harvest sooner. If harvested too soon, the stand level benefits are not achieved (despite reduced harvesting costs). This presents a significant problem as the government has no control over when stands are harvested.

The risk associated with unknown harvest timing and unknown differences in harvest costs must be recognized in analyses. Simply put it likely makes spacing investments less attractive than other possible uses for limited silviculture expenditures. Increased risk is typically accounted for by requiring a higher return on investment to be demonstrated. However moving the required ROI to 4% negates most spacing opportunities at the stand level.

Forest level benefits of spacing are often stated as making the spaced stands available for harvest sooner than the unspaced stands. This is typically based on the time it takes to achieve a minimum average diameter. This approach has been shown time and time again to be seriously flawed. The Ministry's own guidelines for developing stand density management regimes (BC Ministry of Forests 1999a) clearly explain this. Furthermore adding a minimum harvest volume to a minimum average diameter limit does not resolve the issue, as reaching the minimum average diameter is often the limiting factor making the minimum harvest volume irrelevant. In the example provided in Section 6.3.4 when the unspaced stand finally crosses the minimum average diameter threshold it has more than double the merchantable volume and 4.4 times the volume of sawlogs and gang logs than the spaced stand does when it passes the minimum average diameter threshold. The use of minimum average diameter as a minimum harvest criterion clearly sets a drastically different hurdle for the two stands and leads to misleading conclusions about the value of spacing at the stand and forest level. Growth and yield analysts have consistently recommended that average diameter is never used as a determinant of minimum harvest age either alone or in combination with other stand statistics. Forest level analyses could incorporate other measures such as reaching a minimum volume of logs in specified higher end sorts along with a minimum merchantable volume. Although going to this level of analysis one should also incorporate log quality (not just size) into the analysis and this will have a neutral to negative impact on the spacing treatments.

Some foresters believe that management to the current stocking standards with a heavy emphasis on planting with high genetic gain stock and reduced natural in-fill rates due to roadside, low impact harvesting systems and a lack of site preparation has resulted in a lack of stands potentially suitable for spacing (high density stands on good sites where unspaced stands are likely to be more expensive to harvest than spaced stands). In addition in the interior the reduced viability of pine seed from trees killed by the mountain pine beetle is noted as another reason for reduced natural regeneration in harvested areas. Currently some foresters are more concerned about stand densities being too low (for forest health and wood quality reasons) than too high (with the exception of extremely high density fire-origin stands in the interior). Therefore, as an alternative to investment in spacing, FFT may want to consider investment in higher establishment densities on priority sites (where government has responsibility for reforestation and under the appraisal system).

8.0 RECOMMENDATIONS

The following are the recommendations resulting from this project:

1. Preliminary revised FFT funding criteria based on the findings from this project are listed in Appendix V.
    a. Additional changes will be required to these criteria and the juvenile spacing cost caps following the completion of the additional recommended work listed below.
    b. Revisions to the stand selection criteria include only using the forest health information from the FS448, increasing the minimum site indices potentially available for treatment, eliminating unrepressed lodgepole pine from the acceptable species and adding criteria for multi-storied drybelt Douglas-fir.
2. Modify the pre-standing tending survey and prescription templates to ensure consistency with the competing dominant and co-dominant density criteria for even-aged stands and the required layer 1 basal estimates for multi-storied dry belt Fdi stands.
3. Ensure that prescriptions for JS are attached to RESULTS.
4. Complete more detailed site value analyses of coastal stands and sites identified as possible candidates for juvenile spacing.
    a. Our analyses show limited opportunities for juvenile spacing in coastal coniferous stands.
    b. Based on discussions with operational foresters, before proceeding with future juvenile spacing, the Ministry needs to identify stand types where spacing may be a viable option.
    c. Once these stand types are identified, then more detailed analyses of the type we demonstrated in this project should be carried out for these stand types.
    d. These analyses should demonstrate the assumptions (e.g., stand types, differential harvest costs, log values, residual densities, harvest ages) required to provide the stated ROI.
    e. Achieving these assumptions need to be clearly demonstrated and referenced in the future prescriptions to justify the juvenile spacing treatment.
5. Further work is required to justify juvenile spacing of drybelt Douglas-fir stands in ungulate winter range.
    a. Despite the support of many foresters for the multiple benefits of spacing in dry belt Fdi stands in Ungulate Winter Range, the limited analysis which has been done does not show that the ROI threshold can be achieved.
    b. Either more analysis is required, with an emphasis on valuation of non-timber resources and services. Or FFT needs to come up with a different process for rationalizing these investments.
6. The Ministry should set a range of post-treatment densities by treatment objectives to ensure that the required ROI's are achieved. These should be based on additional detailed analysis.
7. Juvenile spacing prescriptions should specify the assumed harvest age range when the stand level ROI criteria are met.
    a. In many situations achievement of the ROI criteria is dependent on assumed harvest age. Therefore without this linkage it is not possible to ensure that the ROI is being achieved.
8. Reference the Ministry's stand density management guidelines (BC Ministry of Forests 1999b) in the silviculture funding criteria and the FFT website.
    a. This comprehensive document should be read by anyone planning juvenile spacing treatments.

9. Ensure that future forest level analyses of juvenile spacing options do not use minimum average diameter as a minimum harvest age criteria.
    a. This approach has been shown to be seriously flawed and overstates the benefits of juvenile spacing.

REFERENCES

Associated Strategic Consulting Experts (ASCE). 2016. Repression density treatment decision key. Contract report to Weyerhaeuser Company Ltd. Princeton, BC.

B.A. Blackwell and Associates Ltd. 2010. Development of an incremental silviculture investment plan for the Tolko IFPA Area. Report 2: Stand level modelling and economic analysis.

BC Ministry of Forests. 1999a. Guidelines for developing stand density management regimes. Victoria, B.C.

BC Ministry of Forests. 1999b. Kootenay Lake timber supply area interim silviculture strategy.

BC Ministry of Forests. 2000. Arrow timber supply area interim silviculture strategy.

BC Ministry of Forests and Range. 2006. Kamloops TSA Type 1 Silviculture Strategy.

BC Ministry of Forests, Lands and Natural Resource Operations (FLNRO) 2012a. Field guidelines for the selection of stands for spacing (coast) FS 448A.

BC Ministry of Forests, Lands and Natural Resource Operations (FLNRO) 2012b. Field guidelines for the selection of stands for spacing (interior) FS 448B.

BC Ministry of Forests, Lands and Natural Resource Operations (FLNRO) 2012c. Post incremental treatment assessment. Final March 31, 2012.

BC Ministry of Forests Lands and Natural Resource Operations (FLNRO) 2013. Using TIPSY 4.3 and FAN$IER in Forests for Tomorrow (FFT) return on investment (ROI) calculations.

BC Ministry of Forests, Lands and Natural Resource Operations (FLNRO) 2014. Silviculture funding criteria 2014/15 to 2018/19.

BC Ministry of Forests, Lands and Natural Resource Operations (FLNRO) 2015. Land based investment strategy 2015/16 to 2017/18.

BC Ministry of Forests, Lands and Natural Resource Operations (FLNRO) 2016. Silviculture funding criteria 2016/17 to 2020/21.

Cortex Consultants Inc. 2000a. Bulkley TSA silviculture strategy (Type 1). Contract report to Prince Rupert Forest Region.

Cortex Consultants Inc. 2000b. Kispiox TSA silviculture strategy (Type 1). Contract report to Prince Rupert Forest Region.

Cortex Consultants Inc. 2002. Fraser TSA silviculture strategy (Type 2). Contract report to Vancouver Forest Region, Forest Practices, BC Ministry of Forests.

Day, K., McWilliams, J. and Daintith, N. 2011. Drybelt Douglas-fir pre-commercial thinning strategy / rationale for the Williams Lake TSA.

Day, K., Brown, C. and McWilliams, J. 2013. IDF strategy for Williams Lake and 100 Mile TSAs.

DWB Consulting Services Ltd., Tesera Systems Inc. and BA Blackwell and Associates Ltd. 2009. Development of an incremental silviculture investment plan for the Tolko IFPA area. Report 1: Stand identification, stand type delineation, application of stand structure classification and silviculture regimes, and assignment of yield curves.

DWB Consulting Services Ltd. 2010. Identification and supervision of intermediate age Douglas-fir stand cleaning and spacing for MDWR within the Tolko IFPA.

DWB Consulting Services Ltd., Tesera Systems Inc. and BA Blackwell and Associates Ltd. 2010. Development of an incremental silviculture investment plan for the Tolko IFPA area. Report 3: Forest estate modelling.

Ecora Resource Group Ltd. 2013. Type 4 silviculture strategy in the Okanagan TSA. Silviculture strategy use report. Contract report to BC Ministry of Forests, Lands and Natural Resource Operations, Okanagan Shuswap Natural Resource District. Vernon, BC.

Ecora Resource Group Ltd. 2016. Type 4 silviculture strategy in the Kamloops TSA. Silviculture strategy report. Contract report to BC Ministry of Forests, Lands and Natural Resource Operations, Resource Practices Branch. Victoria, BC.

Forest Ecosystem Solutions. 2001. Ministry of Forests, Prince Rupert Forest Region, Kalum Forest District, type 2 silviculture analysis report.

Forest Ecosystem Solutions. 2002. Ministry of Forests, Vancouver Forest Region, Sunshine Coast Forest District, type 2 silviculture analysis report.

Forsite Consultants Ltd. 2013a. Williams Lake TSA – Type 4 silviculture strategy. Contract report to BC Ministry of Forests, Lands and Natural Resource Operations, Resource Practice Branch. Victoria, BC.

Forsite Consultants Ltd. 2013b. Quesnel TSA – Type 4 silviculture strategy. Contract report to BC Ministry of Forests, Lands and Natural Resource Operations, Resource Practice Branch. Victoria, BC.

Inland Timber Management Ltd. 2000. Type 2 forest level silviculture analysis report for the Williams Lake Timber Supply Area.

JS Thrower & Associates Ltd. 2003. Impacts of juvenile spacing lodgepole pine stands on TFL 15. Contract report to Weyerhaeuser Company Ltd. Okanagan Falls, BC.

JS Thrower & Associates Ltd. 2005a. Impacts of juvenile spacing lodgepole pine stands in the Merritt TSA. Contract report to Weyerhaeuser Company Ltd. Merritt, BC.

JS Thrower & Associates Ltd. 2005b. Impacts of juvenile spacing lodgepole pine stands in the Okanagan TSA. Contract report to Weyerhaeuser Company Ltd. Okanagan Falls, BC.

Middleton, G.R., Jozsa, L.A., Palka, L.C., Munro, B.D., and Sen, P. 1995. Lodgepole pine product yields related to differences in stand density. Forintek Canada Corp., Vancouver, BC. Pub.No. SP-35.

Silverwood Natural Resource Consultants. 2016. Forest investment opportunities in Northwest British Columbia. An investigation of the second growth forest, opportunities for investment, and outstanding information gaps. Contract report to Coast Mountain Natural Resource District. Terrace, BC.

Silviculture Working Group. 2011. Hardwood management in the coast forest region. File: 00202-20/53908F SWG Hardwood Management Strategy.

Timberline Forest Inventory Consultants Ltd. 1998. Quesnel Timber Supply Area stand treatment analysis, timber supply analysis report. Contract report to Timber Investments Strategy Committee, Cariboo Forest Region. Williams Lake, BC.

Timberline Forest Inventory Consultants Ltd. 2002. Silviculture strategy. Okanagan Innovative Forest Practices Agreement. Type 2 Incremental Silviculture Analysis. Contract report to Tolko Industries Ltd. And the Okanagan Innovation Forestry Society.

Timberline Natural Resource Group Ltd. 2008. Enhanced Type 2 silviculture analysis. Boundary TSA. Analysis package. Contract report to BC Timber Sales.

APPENDIX I – SUMMARY OF TREATED STAND ATTRIBUTES BY DISTRICT

District	Opening ID	Stand Type	Age	Pre-treatment Species Composition	Pre-treatment Density	Post-treatment Density (excluding ghost trees)	JS Cost per hectare (treatment)
DSC	1507970	Dr	8	Dr88Vb6Fd6	2356	800	
DSC	1502352	Dr	10	Dr70Vb27	3730	793	
DSC	1647042 (202a)	FdCwHw	12	Hw52Cw24Fd24	6500	733	$1268
DSC	1647042 (202b)	FdHw	12	Hw36Fd33DrCw	4085	642	$1268
DSC	107884	Dr	8	Dr100	1756	860	
DSC	45308	FdCw	14	Fd55Cw2BgHwDr	2480	733	$794
DSC	80994	FdCw	11	Hw54Fd25CwPwDr	3934	586	$1175
DSC	45294	FdCw	14	Fd56Cw27HwMb	3280	675	$966
DSC	5501	HwCw	19	Hw53Cw37FdDr	3725	700	$955
DCK	90526	HwFd	12	Hw56Fd31CwDecid		782	
DCK	1661942	FdDecidCw	12	Fd33Ep31Cw14Hw	4108	929[12]	$1200
DCK	1661943	HwCwFd	12	Hw58Cw28Fd9	4791	900[12]	$910
DCK	1661898	HwFd	10	Hw73Fd16BaCw	6250	833[12]	$987
DSS	-399920000	HwCwSx	22	Hw60Cw20Sx10Ep10	5560	800	$1384
DSS	-403230000	HwBaSxCw	30	Hw50Ba20Sx10Cw10	4560	941[12]	$1621
DSS	-401950000	BaHw	15	Ba50Hw30Sx10	7400	1050[12]	$1707

[12] Well-spaced trees

District	Opening ID	Stand Type	Age	Pre-treatment Species Composition	Pre-treatment Density	Post-treatment Density (excluding ghost trees)	JS Cost per hectare (treatment)
DSS	16558	HwSx	20	Hw40Sx30Ep10Cw10	6800	800	$1291
DKM	36550	HwBa	17	Hw70Ba30	4720	853[12]	
DKM	36549	HwBa	15	Hw70Ba30	4800	812[12]	
DKM	52215	BaHw	12	Ba60Hw40	5720	787[12]	
DKM	16820	HwBaSx	17	Hw50Ba40Sx10j	5640	798[12]	
DKM	53746	HwBa	16	Hw60Ba40	6040	821[12]	
DKM	1546370	HwBa	17	Hw80Ba20	8533	786[12]	
DKM	1647680	HwBa	17	Hw60Ba40	7885	803[12]	$1665
DCC	1479711	Dry belt Fdi	L3-4; 38	Fd90+	L3-4; 7000; L1 BA=4.5m2	L3-4; 1100	
DCC	1520851	Dry belt Fdi	L3-4; 25	Fd90+	L3-4; 8700; L1 BA=4.5m2	L3-4; 250	$702
DCC	1477490	Dry belt Fdi	L3-4; 25	Fd90+	L3-4; 8700; L1 BA=4.5m2	L3-4; 250	$702
DCC	1479670	Dry belt Fdi	L3-4; 37	Fd90+	L3-4; 5900; L1 BA=4m2	L3-4; 250	
DCC	1479691	Dry belt Fdi	L3-4; 10	Fd90+	L3-4; 4500; L1 BA=4m2	L3-4; 1200	
DCC	1492270	Dry belt Fdi	L3-4; 25	Fd90+	L3-4; 2600; L1 BA=4m2	L3-4; 635	
DCC	1479711	Dry belt Fdi	L3-4; 30	Fd90+	L3-4; 6700; L1 BA=4m2	L3-4; 580	

District	Opening ID	Stand Type	Age	Pre-treatment Species Composition	Pre-treatment Density	Post-treatment Density (excluding ghost trees)	JS Cost per hectare (treatment)
DCC	1646837	Dry belt Fdi	L2-4; ?	Fd90+	L2-4; 7700; L1 BA=?m2	L3-4; ?	$534
DCC	1646819	Dry belt Fdi	L2-4; ?	Fd90+	L2-4; 10,000; L1 BA=?m2	L3-4; ?	$684
DCC	1665619	Dry belt Fdi	L2-4; ?	Fd90+	L2-4; 11,900; L1 BA=?m2	L3-4; 500	$409
DCC	1289630	Dry belt Fdi	L2-4; ?	Fd90+	L2-4; 11,900; L1 BA=?m2	L3-4; 500	$409
DQU	1647245	Multi-layer PlFdSxDecid	L2-4; 20	Pl50Sx20Fd20	L2-4; 5560	L1-4; 1600	$938
DKA	1433011	Dry belt Fdi	L3-4; 35	Fd90+	L3-4; 470; L1 BA=?m2	L3-4; 490	$884
DKA	1440590	Dry belt Fdi	L3-4; 30	Fd90+	L3-4; 6000; L1 BA=?m2	L3-4; 220	$869
DKA	1644322	Pli	11	Pli80At20	9250	1200[12]	$1381
DKA	1644320	PliFdiSxBl	12	Pli30Fd20Sx20Bl20	7815	1200[12]	
DKA	1646201	FdBlSxEp	40	Fd30Bl30Sx20Ep20	8780	1000[12]	$1635
DKA	1661398	EpCwFd	22	Ep40Cw40Fd20	8300	2025[12]	$1439
DKA	1491010	Dry belt Fdi	L2-4; 25	Fd90+	L2-4; 5700; L1 BA=?m2	L3-4; 700	
DKA	1484491	Dry belt Fdi	L2-4; 30	Fd90+	L2-4; 6200; L1 BA=?m2	L3-4; 650	
DKA	1484492	Dry belt Fdi	L2-4; 30	Fd90+	L2-4; 6200; L1 BA=?m2	L3-4; 650	

District	Opening ID	Stand Type	Age	Pre-treatment Species Composition	Pre-treatment Density	Post-treatment Density (excluding ghost trees)	JS Cost per hectare (treatment)
DKA	1491611	Dry belt Fdi	L2-4; 30	Fd90+	L2-4; 6200; L1 BA=?m2	L3-4; 620	
DOS	1297871	Max Density	5	Lw60Pl30At10	224,000	971[12]	$1425
DOS	1009958	Max Density	9	Pl100	19,250	1073[12]	$1227
DOS	1273010	Max Density	3	Pl100	550,100	1200[12]	
DOS	1229293	Max Density		Pl100	273,848	1200[12]	$1147
DOS	1273019	Max Density	4	Pl70At30	86,144	1200[12]	$772
DOS	1229293	Max Density		Pl100	131,447	1200[12]	$1147
DSE	58950	Max Density	22	Fd60Cw20Hw20Ep10	20,000	1540[12]	$1150
DSE	105811	LwHwEpPl	8	Lw43Hw16Cw14Ep12	6696	950[12]	$1080

APPENDIX II – LIST OF PEOPLE INTERVIEWED FOR THIS PROJECT

Aaron Benterud, RPF - FLNRO DKM

Blake Fougère, RPF - FLNRO DSC

Jack Sweeten, RPF - FLNRO DCK

Louise de Montigny, RPF - FLNRO Victoria

Heather MacLennan, RFT - FLNRO DKM

Lee-ann Puhallo, RPF - FLNRO DQU

Julie Castonguay, RPF - FLNRO, DSE

Glen Buhr, RPF - FLNRO, DSS

APPENDIX III – DETAILS OF SITE VALUE CALCULATIONS

BASIC INTEREST FORMULAS

Let V_0 = initial value

i = interest rate (expressed as a decimal – e.g. 8% = 0.08)

n = number of interest bearing periods

V_n = value after n periods.

Compound Interest formula

$$V_n = V_0(1+i)^n$$

This formula allows you to calculate the future value (V_n) of a single present value (V_0) n years from now with an interest rate of i.

Discount formula

$$V_0 = V_n \big/ (1+i)^n$$

This formula allows you to calculate the present value of a single future value. It is simply the reverse of the compound interest formula. This process is called discounting.

Present value of an infinite series of periodic payments

$$V_0 = A \big/ \left[(1+i)^n - 1\right]$$

Let A = per period cash flow amount

This formula allows the determination of the present value of an infinite series of periodic payments of size A made every n years. This is the formula required to calculate Site Value as described below.

NPV OF A SINGLE ROTATION

If the objective is to maximize the returns from a single rotation with no regard for the future use of the land after final harvest then NPV can be calculated as follows:

$$NPV_1 = \sum_{y=0}^{H} \frac{R_y}{(1+i)^y} - \sum_{y=0}^{H} \frac{C_y}{(1+i)^y} = \sum_{y=0}^{H} \frac{(R_y - C_y)}{(1+i)^y}$$

where R_y = revenue received in year y
C_y = cost incurred in year y
i = discount rate
H = final harvest age
and the present is time 0.

What this NPV calculation does not include is a term that accounts for the benefits derived from future rotations, and, at the same time, the cost of foregoing the revenues obtained from future rotations. As a result NPVs for a single rotation cannot be used to compare management regimes having different harvest ages.

SITE VALUE (SV)

Site value is the present value of all cash flows produced by an infinite series of identically managed rotations. It is the value one would be willing to pay for bare ground if the intent was to manage an infinite series of rotations under an assumed management regime. This is why site value is also often referred to as bare land value, soil expectation value, or land expectation value.

When starting with bare ground and comparing alternative management regimes, the regime that has the highest site value is considered the most economically efficient choice.

We have defined the NPV of a single rotation (NPV_1), as the value of the single rotation at time zero (the present). So the value of the same rotation at harvest age (H) would be:

$$= NPV_1 (1+i)^H$$

SV is the present value of an infinite series of identical rotations with the first payment being received in H years. In the following two equations the numerator represents the net value of the rotation at harvest age H. So the site value equation assumes that one is starting with bare ground and will manage the land infinitely under identical management regimes, with the first "payment" being received in H years at the time of the first final harvest and then every H years thereafter.

$$SV = \frac{NPV_1 (1+i)^H}{(1+i)^H - 1}$$

$$SV = \frac{\sum_{y=0}^{H} \left(R_y - C_y\right)(1+i)^{(H-y)}}{\left(1+i\right)^H - 1}$$

When looking in texts or reference manuals be sure to determine whether or not NPV refers to the NPV of a single rotation (NPV_1 above) or includes a term for site value, unfortunately the terminology is not consistent. In FAN$IER, NPV is calculated as NPV_1 and SV is calculated as above.

APPENDIX IV – ADDITIONAL SITE VALUE GRAPHS

All the graphs presented in this appendix have the following characteristics:

- Fd planted, Hw natural stands.
- Spacing done to 750 stems/ha.
- Unspaced site values based on a harvest cost of $55/m^3$.
- All site values based on a 2% discount rate.
- Planting costs at base case rates.
- Log values at base case.
- Nine combinations of spacing and harvesting costs for the spaced stand, all combinations of:
    - $1500, $1750, and $2000/ha for spacing
    - $45, $50, and $55/m^3$ harvest costs.

The graphs differ by:

- Site index.
- Number of planted trees (Fd).
- Number of naturals (Hw).

The graphs are labelled to identify the above differences.

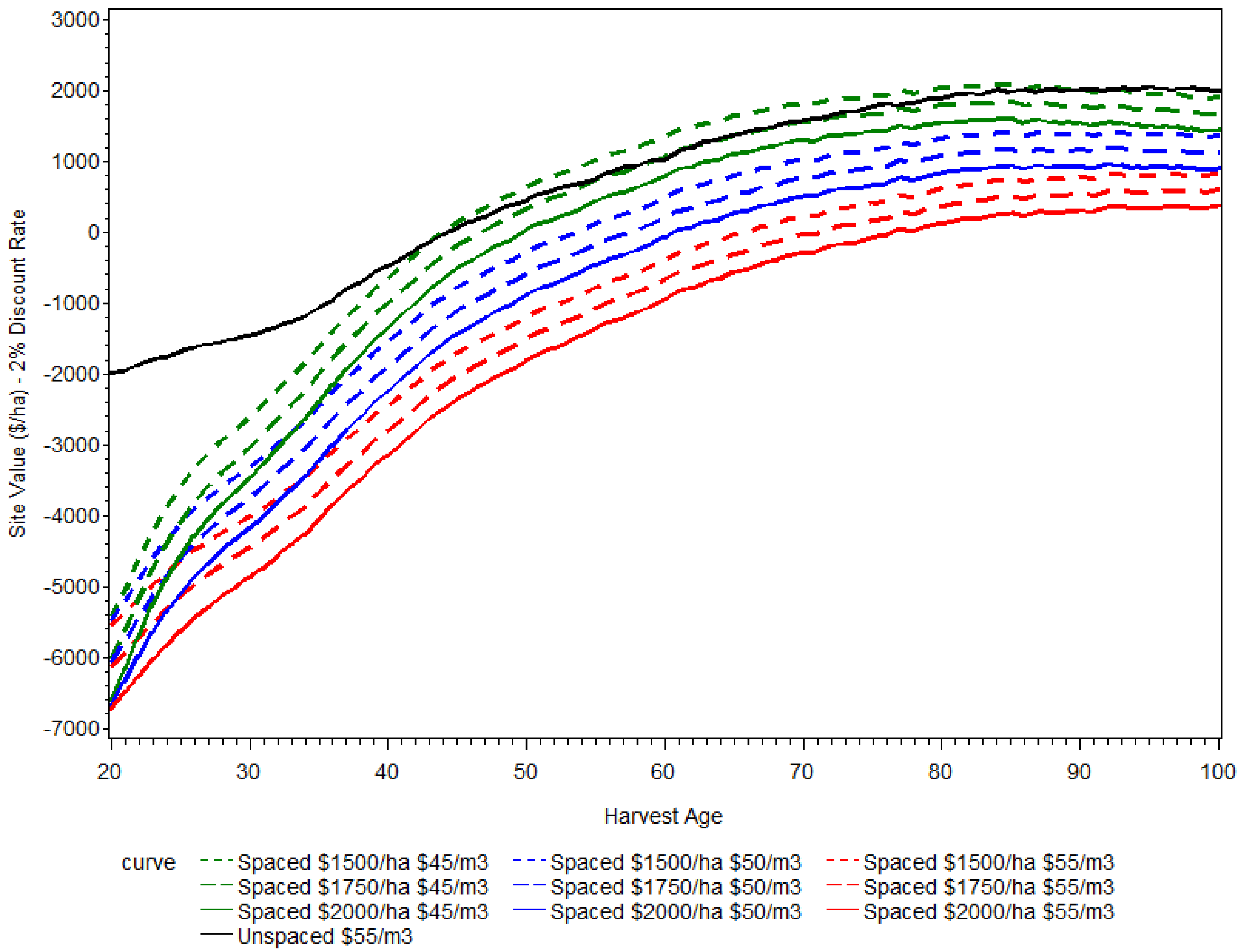

Figure 20. Site values for Fd site index 28, 800 Fd planted and 3000 natural Hw.

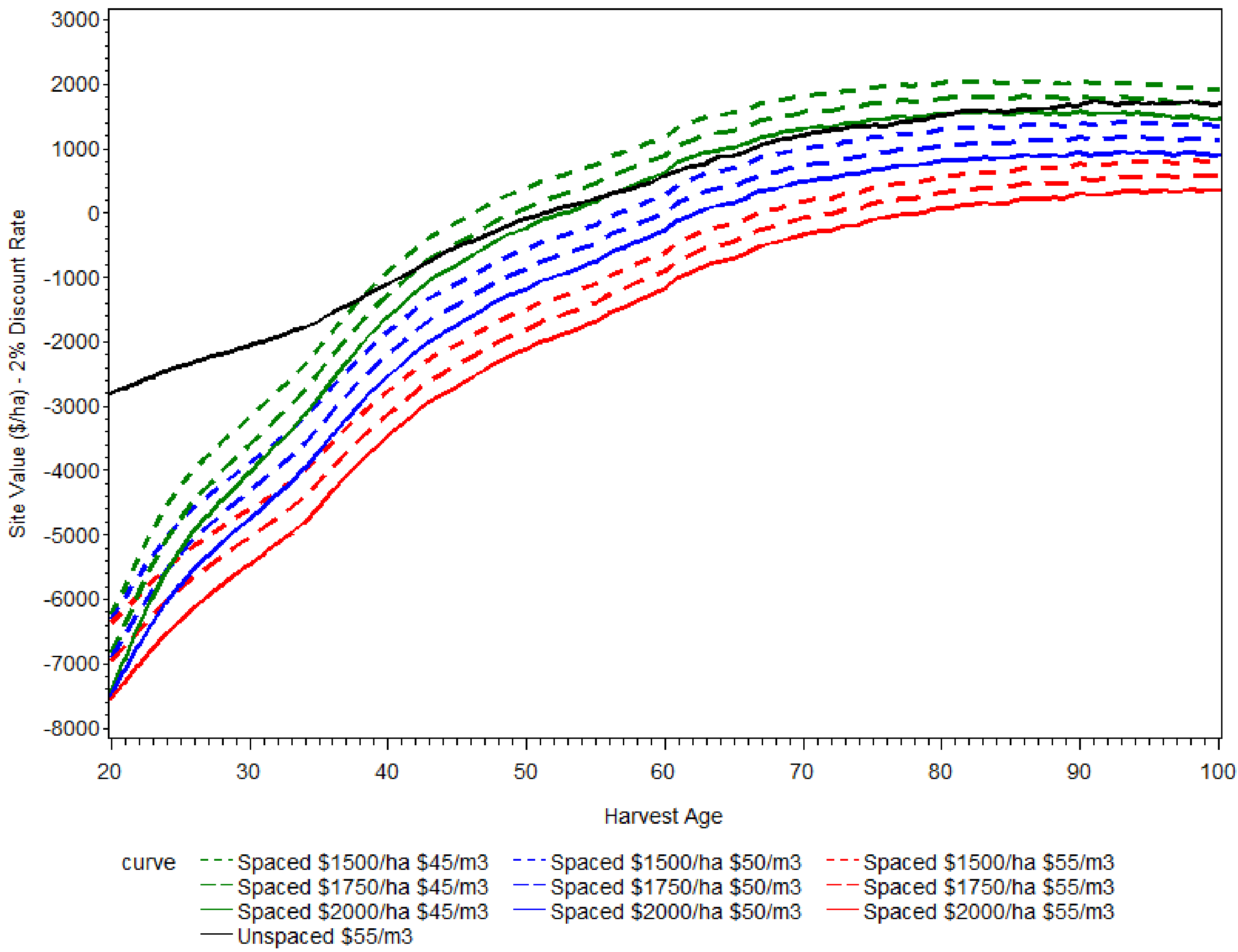

Figure 21. Site values for Fd site index 28, 1200 Fd planted and 7000 natural Hw.

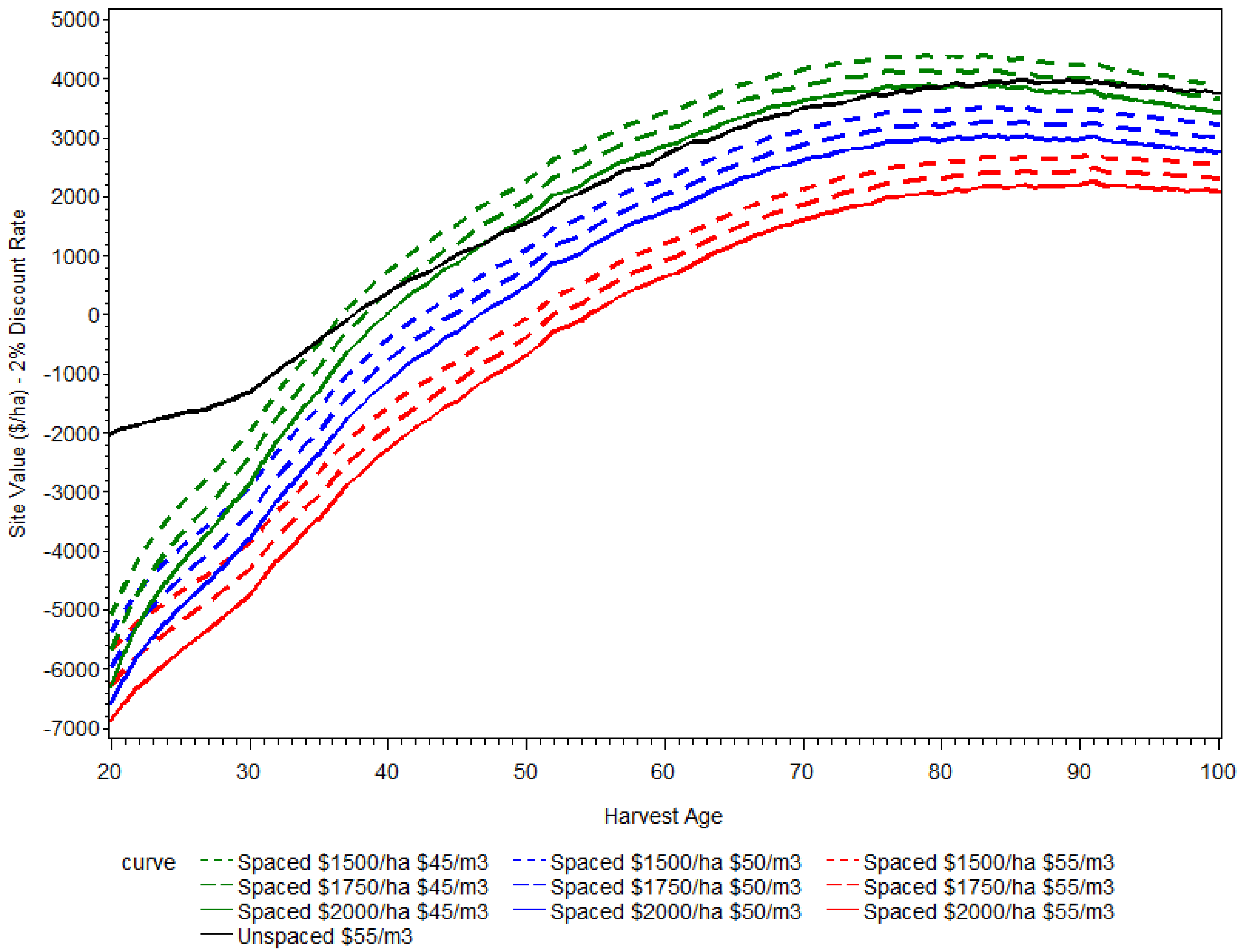

Figure 22. Site values for Fd site index 31, 800 Fd planted and 3000 natural Hw.

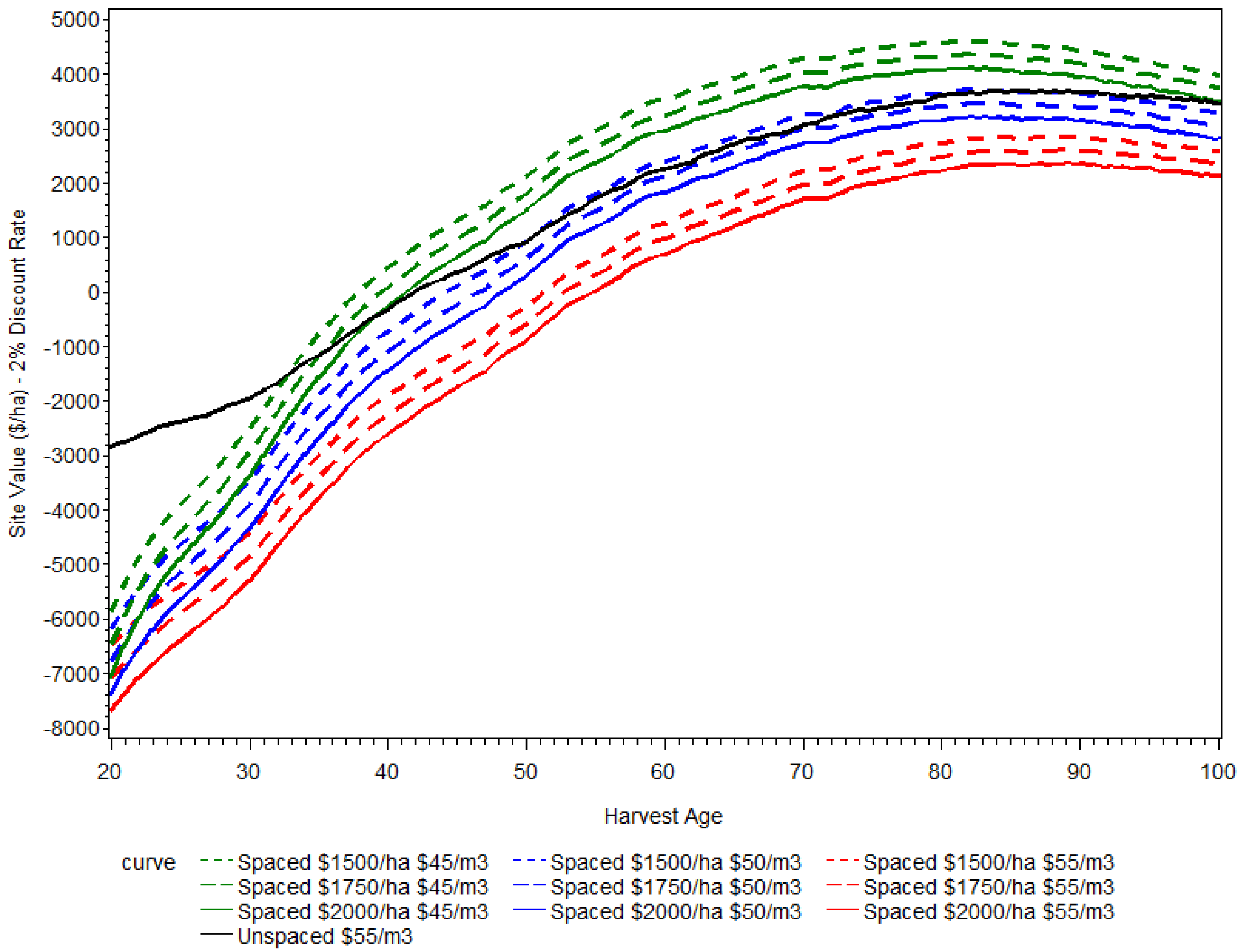

Figure 23. Site values for Fd site index 31, 1200 Fd planted and 7000 natural Hw.

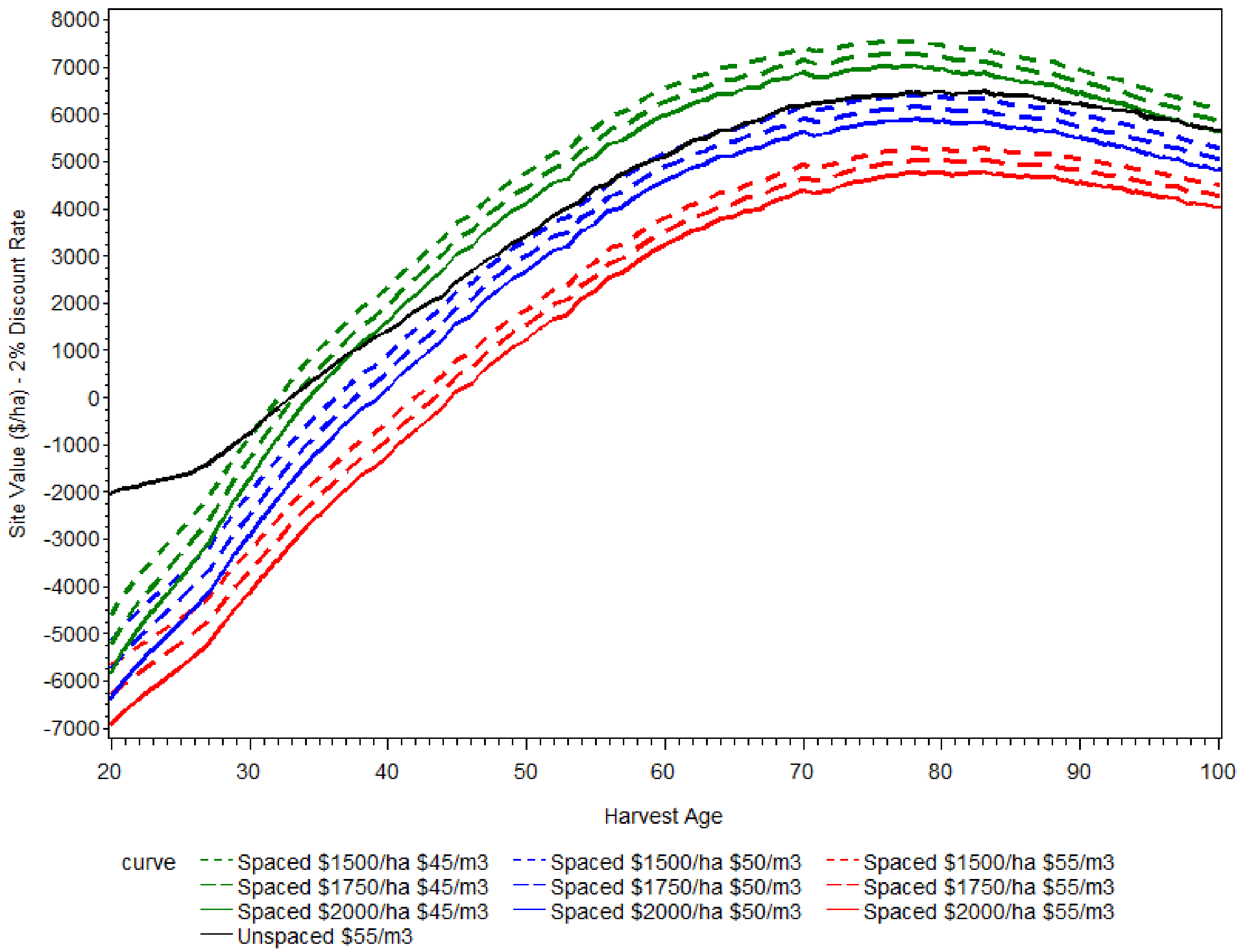

Figure 24. Site values for Fd site index 34, 800 Fd planted and 3000 natural Hw.

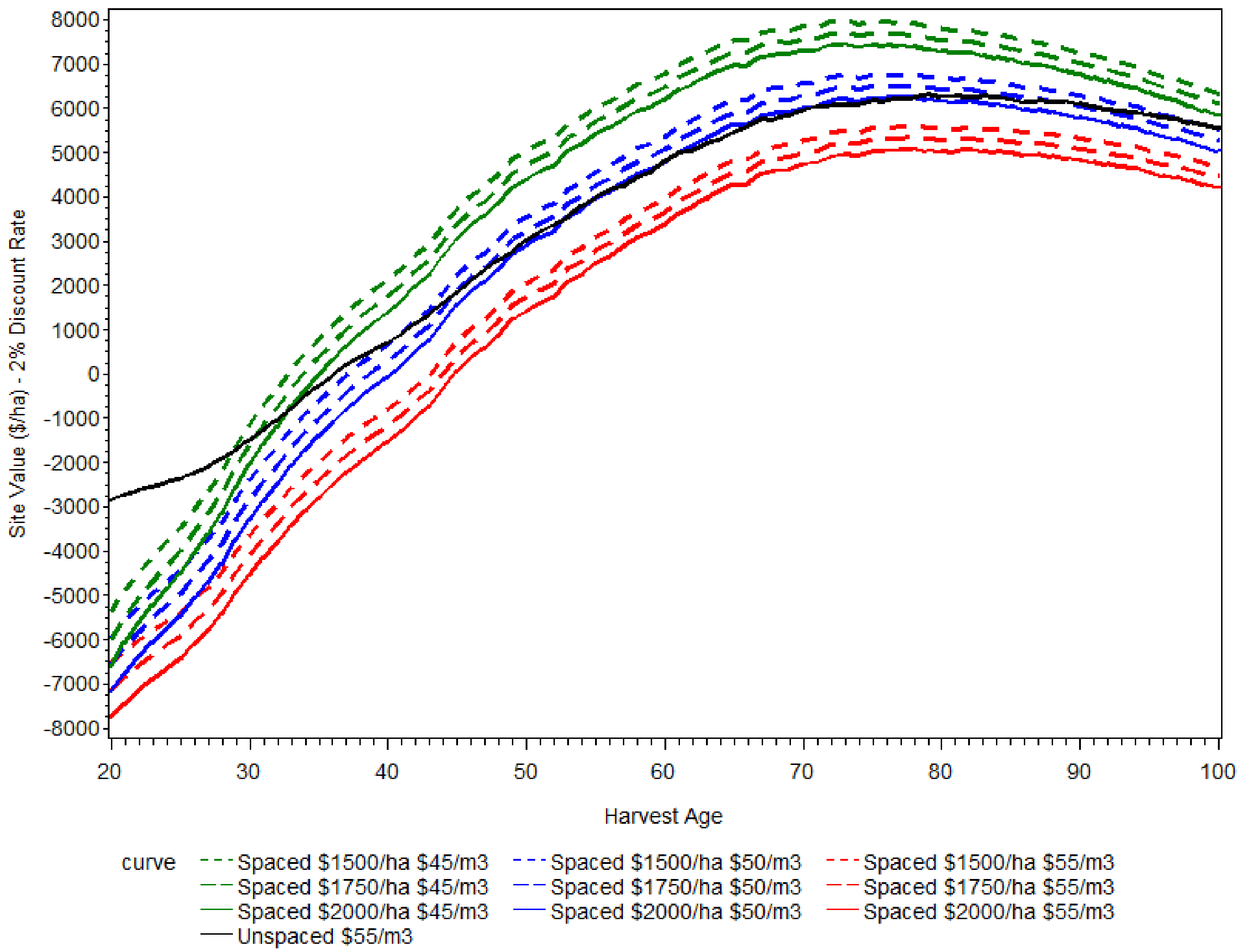

Figure 25. Site values for Fd site index 34, 1200 Fd planted and 7000 natural Hw.

APPENDIX V – RECOMMENDED CHANGES TO FFT FUNDING CRITERIA

Dry belt Fdi Spacing (outside of Mule Deer Winter Range)[13]– Southern Interior:
No current commercial harvest opportunity; <100m3/ha of Fdi with >27.5cm dbh limit.
These criteria should be used in conjunction with the Interior Forest Health Decision Key Matrices included in the FS 448b *Field guidelines for the selection of stands for spacing (interior)*.
Preference will be given in the following order:

Species[14]:
1. Fdi

Site Index[15]:
1. SI >17
2. SI 15-17

Other initial stand conditions:
1. Average Layer 2 to 4 competing density[16] of greater than 2,500 stems per hectare for > 60% of the net treatment area and;
2. Layer 1 basal area of <10m2 per hectare for > 60% of the net treatment area

Forest Health:
- Minimal forest health hazard (use Interior Forest Health Decision Key Matrices in FS448b and consult forest health specialists if there is any uncertainty.)

Spacing – Central Interior:
These criteria should be used in conjunction with the Interior Forest Health Decision Key Matrices included in the FS 448b *Field guidelines for the selection of stands for spacing (interior)*.
Preference will be given in the following order:

Species[17]:
1. Fdi[18]
2. Sx/Sw

Height:
- 2-8 metres

Site Index[19]:

[13] Defined as muli-layered Fdi leading stands in the IDF BEC zone
[14] Post-treatment leading species.
[15] Site index of Fdi based on SIBEC estimates.
[16] Trees competing for light as defined by having <50% live crowns
[17] Post-treatment leading species.
[18] Not including dry belt Fdi
[19] Site index of leading species post-treatment.

1. SI >25
2. SI 22-25
3. SI 18-21

Initial dominant and co-dominant density[20]:
- Greater than 8,000 total competing dominant and co-dominant stems per hectare

Forest Health:
- Minimal forest health hazard (use Interior Forest Health Decision Key Matrices in FS448b and consult forest health specialists if there is any uncertainty.)

Spacing – Coast

These criteria should be used in conjunction with the Coastal Forest Health Decision Key Matrices included in the FS 448a *Field guidelines for the selection of stands for spacing (coast)*.

Preference will be given in the following order:
Species[17]:
1. Dr[21]
2. Fdc
3. Ss
4. Cw
5. Ba/Hw

Height:
- 4-8 metres

Site Index[19]:
1. SI > 32
2. SI 28 - 31
3. SI 22 - 27

Forest Health:
- Minimal forest health hazard (use Coastal Forest Health Decision Key Matrices in FS448a and consult forest health specialists if there is any uncertainty.)

Initial dominant and co-dominant density[20]:
1. Target species Fdc, Ss > 2,500 stems per hectare
2. Target species, Cw, Hw, or Ba > 5,000 stems per hectare
3. Target species Dr >1,500 stems per hectare

[20] Dominants are trees with crowns that extend above the general level of the trees immediately around the measured trees. They are somewhat taller than the codominant trees, and have well-developed crowns, which may be somewhat crowded on the sides, receiving full light from above and partly from the side. Co-dominants are trees with crowns forming the general level of the trees immediately around the measured trees. The crown is generally smaller than those of the dominant trees and is usually more crowded on the sides, receiving full light from above and little from the sides.
[21] Only as part of the Coast hardwood strategy and where stand management is focused on producing short rotation sawlogs.

Spacing - Southeast

These criteria should be used in conjunction with the Interior Forest Health Decision Key Matrices included in the FS 448b *Field guidelines for the selection of stands for spacing (interior)*.

Preference will be given in the following order:

Species[17]:
1. Fdi[22]
2. Sx/Sw
3. Lw
4. Cw
5. Hw/Bl/Ba

Height:
- 4-8 metres

Site Index[19]:
1. SI >25
2. SI 22-25
3. SI 18-21

Forest Health:
- Minimal forest health hazard (use Interior Forest Health Decision Key Matrices in FS448b and consult forest health specialists if there is any uncertainty.)

Initial dominant and co-dominant density[20]:
- Greater than 8,000 stems per hectare.

Spacing - Northwest[23]

These criteria should be used in conjunction with the Coastal Forest Health Decision Key Matrices included in the FS 448a *Field guidelines for the selection of stands for spacing (coast)*.

Preference will be given in the following order:

Species[17]:
1. Cw
2. Sx (where leader weevil risk is low)
3. Ba
4. Hw
5. Bl

Height:
- 4-8 metres

[22] Not including dry belt Fdi
[23] Skeena-Stikine and Coast Mountain Forest Districts.

Site Index[19]:
1. SI>30
2. SI 25-29
3. SI 20-24

Forest Health:
- Minimal forest health hazard (use Coastal Forest Health Decision Key Matrices in FS448a and consult forest health specialists if there is any uncertainty.)

Initial dominant and co-dominant density[20]:
- Greater than 6,000 stems per hectare.