Project number: Y103279

Title: Early survival and growth of natural regeneration and planted seedlings under seven silvicultural systems on the Coast

ABSTRACT

The STEMS experiment (Silvicultural Systems for Ecosystem Management in the Sayward) is a rigorously designed, replicated, long-term experiment that examines the multidisciplinary effects of seven silvicultural systems or extended rotation treatments in coastal forests. The seven treatment regimes include: extended rotation (non-treatment control), extended rotation with commercial thinning, uniform dispersed retention, aggregate retention, group selection, modified patch cuts and clearcut with reserves. These treatments create diversity in forest structure that results in a variety of canopy layers (vertical structure) and spatial patchiness (horizontal structure) that emulate natural variation in forest structure and promotes healthy ecosystem functioning. This project determines differences in survival, growth, and browsing of planted and natural regeneration under each of the treatments four years after harvest and to correlate the differences to light availability across a range of residual tree densities. As well, the STEMS project has had critical baseline measurements taken at STEMS 3 that will be used for subsequent analysis and modeling, now and in future years.

With the conclusion of this 3 year period of FIA funding, early stand development of planted and naturally regenerated seedlings has been collected at STEMS 2. STEMS is a long-term, multi-disciplinary, silvicultural systems experiment with a planned life of 80 years and future stand treatments and the monitoring of permanent plots will be over the course of one rotation. Given the long-term nature of the STEMS experiment, the preliminary information collected here cannot be expected to generate management implications at such a young age. However, the post-treatment baseline information will provide current and future researchers and forest managers the necessary information to continue to derive maximum benefit from the STEMS experiment for solving current and future forest management problems. The results of this experiment will be used to improve environmental management and policies because results can be directly interpreted operationally due to the large-scale, replicated experimental design. The information will be especially relevant for forests with high multiple-use demands.

INTRODUCTION

Clearcutting has been the primary silvicultural system applied on the coast over the last century and we have become very skilled at timber management on many types of terrain in varying climates. But with increasing public demand for forests with multiple uses including timber, recreation, non-timber forest products, and diverse wildlife habitat, clearcutting has become increasingly socially unacceptable. The forest industry is increasingly using alternatives to clearcut harvesting, but there is currently a lack of reliable scientific data to support decision-making regarding the use of alternative harvesting practices. Existing research studies have addressed various components of differing partial cutting systems, mostly in old-growth stands. However, no examples are available on the coast of silvicultural systems in second-growth stands, other than clearcutting, that have been systematically applied over an extended period of time and area, and that have the data collection necessary to make sound quantitative comparisons of their biological, financial, and social results.

The Silviculture Treatments for Ecosystem Management in the Sayward (STEMS) project is a large-scale, multi-disciplinary experiment that compares forest productivity, economics, and public perception of 7 treatments replicated at 3 sites in the Sayward Forest. The treatments include 5 different silvicultural systems: clearcut, patch cut, group selection, aggregated retention and uniform dispersed retention, which are compared against 2 extended rotation options, with and without commercial thinning.

The Sayward Forest, also known as the Sayward Landscape Unit or “the Sayward” exemplifies the increasing multiple-use demands on forest resources. The Sayward Landscape Unit (LU) covers 112 000 ha in the Campbell River Forest District. Over the past century, logging or fire has disturbed most forests in the Sayward such that 63% of the area consists primarily of second-growth forests between 40 and 80 years old. The few old-growth stands remaining are fragmented and primarily at higher elevations. The Sayward has an extremely valuable recreation resource, with a large concentration of lakes, karst/cave areas, and significant scenic values. Along with three provincial parks, the Sayward includes 67 Forest Service recreation sites, and numerous hiking and mountain biking trails. The Sayward also features important wildlife habitats, cultural and heritage resources, mineral values, a source of domestic water and of non-timber forest products such as salal, mushrooms, and berries. With a 20 to 50% predicted rise in population on eastern Vancouver Island (Vancouver Sun, March 22, 2002), the demand for resources in the Sayward is expected to increase dramatically in the next decade.

The Vancouver Island Land Use Plan and the Sayward Landscape Unit Plan have identified the importance of the multiple resource use in the Sayward and characterized the area as a General Management Zone. The overall goal is to promote timber harvesting and production in accordance with principles of integrated resource management that consider all resource values, with stewardship guided by the principle of sustainable use. Ecosystem management techniques can be used to achieve these goals.

Ecosystem management applies ecosystem-ecology concepts to managing forests, fully recognizing the complex interactions between biotic and abiotic components and ecosystem processes and resulting patterns. Therefore, sustainable ecosystem management should consider the natural patterns of forest structure and dynamics. Systematically fostering a balanced distribution in time and space of many stand conditions and stages of stand development can sustain diverse, multiple values in specific forest landscapes (DeBell and Curtis 1993).

Silviculture can be used to create gap sizes and frequencies that emulate the variation in forest structure and openness among different site types and ecological zones. However, according to Lertzman and others (1996), the natural disturbance cycle timelines for west-coast forests are so long that any traditional even-aged management system is highly unlikely to maintain or recreate the structural characteristics that dominate the forests they examined. These disturbance cycles are still longer than if rotation lengths were increased beyond what is considered economically feasible.

In traditional silviculture terminology, creating small gaps is equivalent to group selection involving the removal of 3–10 stems. Small group selection would provide regeneration opportunities similar to those within intact forests and maintain an uneven age structure with trees of varying age, height, and diameter distributed patchily in a fine-grained mosaic. However, Douglas-fir does not successfully regenerate and reach the canopy in gaps less than about 700–1000 m^2 in the Western Hemlock Zone (Franklin and Dyrness 1973) because light levels may be too low. Also, most canopy gap events, which are usually formed by standing dead trees or by top breakage, do not form gaps in the lower strata of the forest or expose mineral soil, which Douglas-fir germinants prefer to organic seedbeds (Minore 1979). For this reason, larger gaps and soil disturbance should be created to specifically regenerate Douglas-fir.

Modifying conventional silvicultural practices and additional measures can actively enhance stand characteristics favourable to some biodiversity, wildlife, and aesthetic goals (Curtis et al. 1998). These include:

- modified thinning practices to develop mixed species stands, multiple canopy layers, and more diverse understories. Irregular thinning and underplanting of openings with tolerant species can be used to promote vertical and horizontal heterogeneity;
- thinning, especially if begun early, to produce large trees with deep crowns and a more open environment for understory development. Early thinning minimizes the duration of the least diverse and least productive (for wildlife) stem exclusion stage of stand development;
- retention of some hardwoods and minor species in thinning can enhance species and structural diversity;
- protection or retention of standing dead and down trees, where feasible, for nest sites and coarse woody debris;
- protection of live trees with cavities as nest sites;
- creation of snags, cavity trees, and down trees in stands where they are scarce or absent; and
- use of extended rotations (in combination with thinning) and alternative regeneration systems to develop a wide range of stand ages, tree sizes, and structures.

To maintain the range of old-growth–like habitats at the stand level requires the continuing presence of large-diameter snags and down logs (Scientific Panel for Sustainable Forest Practices in Clayoquot Sound 1995). Windthrow should be included as part of the management strategy to leave downed woody debris.

Maintaining a range of stand structures across a landscape provides consistent employment in silvicultural operations and in the use, manufacture, and remanufacture of wood products. Retaining diverse stand structures across the landscape also offers a sustained supply of various forest values—low-quality timber products from thinnings, high-quality timber products from harvesting previously thinned forests (which simultaneously produce habitat in the stand-initiation stage before trees regrow), and other forest values such as recreation, mushrooms, scenery, floral greens, and berries. Non-timber forest products will probably never produce as much revenue as timber; however, they can make certain silvicultural practices, such as thinning and pruning, more economically attractive as well as increase employment diversity (Oliver 1992).

The STEMS (Silvicultural Systems for Ecosystem Management in the Sayward) experiment uses many of these silvicultural treatments for ecosystem management. The results of this experiment will be applicable to coastal regions and other areas of the province, especially areas that are at the urban interface and are visually sensitive. These treatments could also be used in areas of high recreation use, critical wildlife habitats, or unstable terrain; community watersheds; or areas where maintaining a high degree of stand-level biodiversity is desirable.

The STEMS experiment is a rigorously designed, replicated, long-term silvicultural systems experiment that tests 7 treatments: an extended rotation (non-treatment control), an extended rotation with commercial thinning, aggregated and dispersed retention systems, group selection and patch cut systems, and a 10-ha clearcut. The 7 treatments will be replicated at 3 sites. The first replication (STEMS 1) was established in the Snowden Demonstration Forest and harvested through the Small Business Forest Enterprise Program in 2001 and consists of a second-growth unmanaged stands of Douglas-fir and an understory of western redcedar. The second site was established near Elk Bay and harvested by Interfor in 2004 and consists of dense stands of western hemlock and Douglas-fir. The third site harvested by BC Timber Sales in 2007 is composed of commercially-thinned Douglas-fir.

The overall goals of the STEMS project are, within mature second-growth Douglas-fir stands:

- to create replicated examples of alternative harvest practices and silvicultural regimes that can be used as a demonstration area by foresters and planners in ecosystem management;
- to provide quantitative information for evaluation of feasibility and costs of alternative regimes and of their long-term effects on production of timber volumes and values and other non-timber values; and
- to evaluate the effectiveness of contrasting silvicultural systems in reducing environmental and visual impacts of forestry operations, while supplying high timber outputs over time.

The STEMS project has both scientific and extension objectives:

1. Scientific

a. To quantitatively compare forest productivity, including residual trees, regenerating trees, understory vegetation, light environments, mortality and windthrow, and coarse woody debris, under contrasting silvicultural systems over an extended time period.
b. To quantitatively compare timber outputs, production costs, and operational factors associated with harvesting, including post-harvest residual tree damage, soil disturbance and compaction, and slash loading.
c. To quantitatively compare the public response to the various silvicultural treatments.

2. Extension

a. To create 3 replicated examples of 5 silvicultural systems and 2 extended rotation treatments that can be used as demonstration areas by foresters and planners in ecosystem management and as experimental areas for scientists studying ecosystem dynamics.

b. To facilitate the interpretation of forest management implications and the application of 7 silvicultural systems or extended rotation treatments by providing current information about the biological, economic, and social results of the STEMS project to all interested audiences in a timely and appropriate manner.

Planned work objectives for the FIA-funded project:

1) To complete yearly surveys at STEMS 2 of planted and natural regeneration and windthrow across a range of silvicultural systems, residual tree densities and treatment regimes.

2) To analyse the data so as to determine:

   a. how residual stand structure and corresponding light availability under 7 silvicultural systems affects natural regeneration and planted Douglas-fir and western redcedar seedling survival, browsing, and mortality over 4 years at STEMS 2.
   b. the total occurrence of windthrow across the 7 silvicultural systems and extended rotation treatments after over 4 years at STEMS 2.

3) To ensure the results are extended to the forest community by writing a technical report or journal article (depending if the results are journal-worthy) and an extension note.

As well, if cost-savings were realized or additional funds were made available, then additional work to complete the post-treatment measurements at STEMS 3 was also done. STEMS 3 is the third and final replication of the STEMS experiment and is unique in that each of the treatment units consist of commercially thinned Douglas-fir. The treatment units were harvested through BC Timber Sales in 2008. Post-treatment work done with assistance of FIA and other partners included plot reestablishment, regeneration surveys, residual tree measurement, coarse woody debris surveys, soil disturbance surveys and erection of the above-canopy light sensor. Finally, a cost and productivity study was completed by FPInnovations.

METHODS

1. STEMS 2

a) Regeneration surveys

Regeneration was assessed on a 3.99 m radius (0.005-ha) plot located on each cardinal point 17.8 m from the permanent plot centre (main plot is 0.10 ha). Surveys were done on all harvested plots, which varied with treatment.

Within the marked circumference of the subplot, all planted trees were tagged and measured, and naturally regenerated trees tallied as described below. Distance from the plot centre to the stem centre of trees situated close to subplot boundaries were accurately measured, to determine whether the tree was included as a sample tree.

Tags were attached to wire and looped very loosely around the base of the seedling. Species was identified and height measured to the nearest centimeter. Root collar diameter was measured using calipers to the closest millimeter. Seedling health was assessed using appropriate coding listed below.[1]

For natural regeneration, the following tree size classes were identified:[2]

- germinants (< 10 cm tall)
- seedlings (10 cm – 1.3 m height)
- saplings (> 1.3 m height but < 4 cm dbh)

Only the tallest and second-tallest acceptable seedlings[3] in the subplot were tagged and measured. Tags were attached to wire and looped loosely around the base of the seedling. Species was identified and the seedling measured for height to the nearest centimeter. Root collar diameter was measured using calipers to the closest millimeter. Seedling health was assessed using appropriate coding[4] as listed below.
Photographs of each plot were taken from the south boundary of the subplot facing towards the subplot centre post. The corresponding plot number and photo number were recorded.

b) Windthrow surveys

Windthrow at edge measurements were conducted at STEMS 2 in July 2007 and March 2009 and 2010. The procedure is described as follows:

- Locate tie point that is easily identifiable on map or air photo and record Point of Commencement (POC) northing and easting as measured by hand-held GPS.
- Begin traverse notes on left side of book and map edge to 1:5000 scale on right side of book.
- Record random half sweeps with 4BAF prism to record basal area in parts of edge that are not windthrow-affected.
- Create a station wherever windthrow occurs and subsequent stations every 20 or 30 m through any windthrow patches.
- Record half sweeps with 4BAF prism along windthrow-affected edge segments.
- Record the extent and the azimuth of windthrow patches. Note that the extent is determined by the location of the root system of the farthest uprooted tree.

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[1] Based on coding established by the Expert Committee on Weeds.
[2] Tree size classes are from the *Stocking and Free Growing Survey Procedures Manual* May 2002, Forest Practices Branch, B.C. Ministry of Forests.
[3] An acceptable seedling is one that is free from deformity or injury likely to prevent development into a merchantable tree.
[4] Based on coding established by the Expert Committee on Weeds.

- Dominant orientation of individual trees affected by windthrow is indicated graphically on the mapping side of the notes with relative numbers of trees affected (e.g., one tree drawn in notes indicates isolated trees affected, two trees indicates small patch, and three or more trees indicates larger patch). The orientation of individual trees will be deduced from the azimuth along the traverse in the field notes. Dotted lines were used to indicate the shape and size of any large patches of windthrow, and information regarding significant landmarks such as road location and orientation and block corners were also recorded on the mapping side of the notes.
- Traverse may be open, with Point of Termination (POT) identified by new GPS co-ordinates, or closed, by returning to the POC. Long stretches of edge, which were obviously not affected by windthrow, were not traversed.

c) Light data collection

A mast was installed for the collection of above-canopy light data. Light data are collected using a combination of quantum sensors (LI-190SA) (LI-COR Inc., Lincoln, Nebr.) and gallium arsenide phosphide photovoltaic cells, and hemispherical canopy photographs (fish-eye photos) using a Nikon Cool-pix 5400 with a 190° field of view. Fish-eye photos were taken at 1.5 m over every regeneration plot centre, over a 2 year period from planting. The above-canopy light data was used to calibrate the fish-eye photos. The corrected light measurements are expressed as seasonal PACL (Percent of Above Canopy Light) and as PPFD (Photosynthetic Photon Flux Density).

2. STEMS 3

a) Plot relocation

GY treatment plot centers were reestablished in those treatment units where harvesting had occurred including group selection, clearcut with reserves, aggregated retention, uniform dispersed retention and patch cut corresponding to treatment units 1, 2, 3, 5 and 6 respectively.

b) Regeneration surveys

Planted and natural regeneration were surveyed as described under STEMS 2 description above. Planted trees were tagged and measured on any regeneration plots that fell in harvested areas and natural regeneration was surveyed and measured in all regeneration plots.

c) Residual tree remeasurements (funded under project FIA-FSP Y103073 Coastal Stand Management Growth and Yield Field Experiments)

The overall sampling scheme for residual trees consists of periodically remeasured fixed-area tagged tree plots located on a permanently monumented systematic grid within each treatment unit (an operational block). Spacing, number, and arrangement of plots depend on size of area and expected post-treatment stand heterogeneity. Sample size was based on the expected post-treatment, not pre-treatment, stand structure condition. Treatments resulting in even-aged stand structures would require fewer samples than those resulting in multiple-age structures. The objective is to achieve about equal precision in estimates of means in all treatments, combined with precision as high as can be obtained at acceptable cost. The following number of permanent growth and yield plots were established:

- Block 1 – Group Selection: 21
- Block 2 – Clearcut with Reserves: 18
- Block 3 – Aggregated Retention: 25
- Block 4 – Extended Rotation with Commercial Thinning: 16

- Block 5 – Uniform Dispersed Retention: 21
- Block 6 – Patch Cut: 27
- Block 7 – Extended Rotation (Non-Treatment Control): 17

For detailed methodology about residual tree measurement for the STEMS experiment see de Montigny and Nigh, 2008.

d) Soil disturbance surveys (not FIA-funded)
Soil disturbance surveys were done as described in the "Survey methods for soil disturbance and forest floor displacement"and "Transect method for areas 10 hectares and smaller" sections (pages 29-37) of the Forest Practices Code of B.C., Soil Conservation Surveys Guidebook, January 1997. The treatment units were stratified based on site series and stumping as follows:

Block	System	Sub	NAR	Site Series	% Site Series	Stumped	Strata ID
1	**Group**	GS 1,4,7,9,11	0.82	05	~100		1
	Selection	GS 5	0.05	07	~100		2
	2.7 NAR	GS 8,10	0.79	05/07	mixed	Yes	3
		GS 2,3,6	1.02	05/07	mixed		4
2	**Clearcut**	a	14.9	05	60		5
	w reserve			07	20		6
	38.7 NAR	b	23.8	05	60		7
3	**Aggregate**	a		05	80		9
	Retention	b		07	20		10
	35.1 NAR						
5	**Dispersed**	a		05	70		11
	Retention	b		07	30		12
	37.8 NAR						
6	**Patch**	PC 1	0.8	05/07	mixed		13
	Cut	PC 2	1.1	05/07	mixed		14
	3.8 NAR	PC 3	1.9	05/07	mixed		15

Detailed methodology for the contracted work is as follows:

- The Contractor will field mark, using field flagging and/or spray paint, the strata to be surveyed to ensure boundary of strata is clearly visible. The Contractor will report field-marking method (flagging colour) to the Contract Co-coordinator on an associated site map. The Contractor will field mark a distinguishing soil disturbance survey identification number, date and surveyor's initials.
- The Contractor will field mark the starting and ending location of each transect line used in the survey of each stratum. Each transect line to be field marked at each end as either "start" or "end", transect distinguishing identification number or letter, and bearing in azimuth.
- For each stratum surveyed, the Contractor records soil disturbance summary information as listed in field card FS 889 HSP 96/10. The Contractor will use soil disturbance hazard

rating(s) as listed in Appendix I below or as otherwise directed by the Contract Co-coordinator.

- The Contractor will record approximate location of strata and transect lines (field information developed in sub-sections 4 and 5 above) by sketching a site map on back of field card FS 889 HSP 96/10. Site map will include approximate location of north arrow, strata unit boundary in relation to identifying feature (e.g. road or major stream), prevailing yarding direction, baseline location (if used) and starting and ending point of each numbered transect line.
- The Contractor will record soil disturbance and forest floor displacement categories on Transect Survey Field Card FS 885 HSP 96/8 (see Appendix III of this agreement).
- The Contractor will take a limited number of print photographs of representative examples of soil disturbance categories found in each stratum.
- The Contractor will calculate and record soil disturbance survey summary information on field card Small Area Survey Calculation Card FS 897 HSP 96/9.
- For each stratification unit surveyed, the Contractor will write a brief (half page) description of the site, list survey results, identify the most common soil disturbance categories observed and provide surveyor's impression of the regeneration potential for the sites compared to the adjacent area.
- For each strata surveyed, the Contractor will supply the Contract Co-coordinator with three (3) original copies of the survey site write-ups, site map(s), transect survey field cards and photographs (identifying the associated soil disturbance category) to the Contract Co-coordinator.

e) Coarse woody debris surveys (not FIA-funded)

Post-Harvest Coarse Woody Debris surveys were conducted on twenty-one plots in the STEMS 3. Eighteen plots in Block 2 - the Clear Cut, and three plots in Block 6 - the Patch Cut. Block 2 was mechanically harvested except for the steeper ground in the SW corner, which was hand-felled. The site conditions varied from moderate slash, with debris accumulations and compacted slash, to fairly clean and open. Some areas had pulled stumps and large slash piles, but these tended to be closer to the roads and did not affect the CWD transects. Block 6 was also mechanically harvested. The two patches that contained CWD plots had moderate slash throughout, with some heavier areas and some stumped areas.
The sampling method consisted of three transects, each twenty-five (25) meters horizontal distance from plot center and separated by one hundred twenty (120) degrees. The azimuths used during the pre-harvest CWD survey were provided and were used to establish the post-harvest transects. Each transect was established from plot center at the prescribed azimuth and slope corrected to twenty-five meters horizontal distance. The tape was then fastened tightly to the ground to mark the transect location. The end of each transect was marked with flagging tape with the plot number, transect number, and transect azimuth and distance written on the tape. Starting from plot center, each CWD piece had it's transect intersect point marked with blue paint and was numbered sequentially. Where there was no CWD a blue paint stripe was painted on the ground to mark the transect location. In some plots in the Clear Cut where the transect reached the boundary of a Wildlife Tree Patch, or in the Patch Cut where the transect reached the patch boundary, the Bounce Back procedure was used. If, for example, the boundary was reached at the 15 meter mark, the transect would bounce back along its length for 10 meters to give the full 25 meters. Any piece encountered in that 10 meters, though already tallied, would be tallied again as a new piece.

Each numbered round or semi-round piece of CWD was coded for Species, for Piece Type (Log, Branch, Windfall, Fragment), and for Shape (Round, Ellipse, Half-ellipse, Slab). The vertical angle was measured with a clinometer to the closest degree, and the horizontal orientation measured with a compass, facing from the butt end of the piece toward the top. Measurement of each piece began at the transect intersect point with Inside-Bark Width and Height (measured with 65 cm Hagloff calipers), Bark Thickness, and Transect Intersect Length. Bark at the transect point was coded for Loose or Firm, and given a percent remaining code. Measurement of Inside-Bark Width and Height, and Bark Thickness were also done at the Butt and the Top of each piece, and each was coded for Description (New cut, Old cut, Natural, Broken, Under). The lengths of each piece to the Left and Right of the transect were taken to the nearest 0.1 meter, and these lengths were combined to give the Total Net Log Length. If the end was broken or shattered it was 'Folded" to give an approximation of sound-wood length. "Folded" lengths were marked with blue paint, as were the 10 cm top cutoff points on unbroken tops. Pieces that were broken but with segments separated by less than 0.5 meters were measured as one piece (with separations not included in length measurements). Pieces separated by more than 0.5 meters were measured as Second Top, Second Butt, etc. with piece numbers S1, S2, etc. Their lengths were added to the original piece's Total Net Log Length. Each piece was given an Ecological Code representing its stage of decay (a five-point scale ranging from newly dead and intact to the final stages of decay); a Grade for the transect piece using VRI grade rules; plus the Z grade for sound-wood reject; and a Soundness code (a four-point scale representing % sound). In addition, each piece was coded for the presence and type of Rot and for the presence or absence of Charcoal. Where there was butt-rot present this volume loss was measured as Hole Width, Hole Height, and Hole Length. Odd-shaped pieces, mostly fragment of old Cedar stumps broken up by machinery, were measured only for width and height along the transect intersect, and given Eco Code, Grade, and Soundness Code.

f) Erection of the above-canopy light sensor

A mast has been installed for the collection of above-canopy light data. Light data are collected using a combination of 2 quantum sensors (LI-190SA) (LI-COR Inc., Lincoln, Nebr.) and hemispherical canopy photographs (fish-eye photos) using a Nikon Cool-pix 5400 with a 190° field of view. Fish-eye photos will be taken at 1.5 m over the centers of each GY plot and regeneration subplot, as soon as possible after planting to build a light grid across the treatment unit. The above canopy light data will be used to calibrate the fish-eye photos. The corrected light measurements will be expressed as seasonal PACL (Percent of Above Canopy Light) and as PPFD (Photosynthetic Photon Flux Density).

RESULTS

1) STEMS 2 Regeneration Study

The FIA-FSP study examined the effects of the seven treatments on planted and natural regeneration and windthrow 2, 3 to 4 years after harvest. Fourth year results have not been summarized at this time because of government delays in contract approvals which resulted in a delay in receiving the final measurement data until March. The fourth year data will be analyzed along with the light data in the coming months. Results for years 2 and 3 are as follows:

- Mortality was highest in the second year after planting and was highest in the group selection treatment (6%). Mortality in the third year was minimal (1 to 3%) and occurred only in the clearcut and dispersed retention treatments. Mortality
- Planted Douglas-fir height after 3 years averaged about 1 m in all treatment units except the modified patch cuts in which it was less than 80 cm. Planted western redcedar height was between 70 and 80 cm.
- Browsing on Douglas-fir in the second year was low (1 to 7%) compared to western redcedar (21–30%). In the third year, browsing on Douglas-fir was higher especially in the group selection and modified patch cut (66% and 59% respectively), compared with

western redcedar (28% and 31% respectively). Protection of western redcedar seedlings with Sinocast tree cones likely limited the amount of browsing.

- Density of natural regeneration ranged from 1400 to 16400 germinants per ha and 2200 to 13400 seedlings per ha with the group selection having the highest natural regeneration density of all treatment units.
- Douglas-fir was the tallest naturally regenerated species in the clearcut, dispersed retention and group selection treatments (50 to 70 cm). Western hemlock was the tallest in the dispersed retention treatment (about 1 m).
- Windthrow was highest in the second year after harvest. The aggregated retention treatments was most strongly affected and had only 37% of residual trees still standing after 3 years, followed by the dispersed retention and extended rotation with commercial thinning treatments that had 65 and 70% residual trees still standing. Most trees that were leaning after the second year had fallen by the third year.
- The experiment is a long-term experiment and preliminary results cannot be expected to generate management implications at such a young age. However, the data generated from this experiment are being used for calibration and validation of models for early growth and yield in complex stands and windthrow.

2) STEMS 3 Post-treatment Measurements

Post-treatment data was collected at STEMS 3 for planted and natural regeneration, residual trees, coarse woody debris and soil disturbance. Data has not been summarized for STEMS 3 as contracts were completed in the last 2 months of the fiscal year and data is still being checked for accuracy. An establishment report for STEMS 3, as for STEMS 1 and 2, will be written to document the details of the procedures used, describe the pre- and post-treatment conditions and provide details about each of the treatments and how they were harvested.

EXTENSION

1) Data
   a) STEMS 2
      i) planted and natural regeneration growth, vigour and health for each treatment unit
      ii) occurrence of windthrow in each treatment unit
      iii) Light availability data from each regeneration/vegetation plot within each treatment unit.
   b) STEMS 3
      i) planted and natural regeneration growth, vigour and health for each treatment unit
      ii) residual tree surveys on all plots across each treatment unit
      iii) Coarse woody debris surveys on 21 plots in 2 treatment units
      iv) Soils disturbance surveys on 5 treatment units

   Target audience/end user: Forest Modelers – Forest Service (Jim Goudie, Mario Di Lucca) and UBC (Steve Mitchell and Ken Byrne) modelers.

   Benefits to target audience - The data from the STEMS project will be incorporated into models; specifically TASS 3 simulating the management, growth and yield of complex stands; the ForestGales model used to assess the windthrow yield losses after variable retention harvesting, and subsequently, incorporating the ForestGales results into TASS and TIPSY.

2) Technical reports and journal articles
   a) The STEMS 2 establishment report has been published as a technical report (de

Montigny and Nigh 2009) with the intent to preserve details of the procedures used and the data collected for researchers and forestry practitioners who will use and interpret the results of this study. The report documents the experimental design, goals and objectives; site details including detailed location, block and plot maps, resource assessments, ecosystems classification of treatment units; a summary of the silviculture prescription; the harvest treatments; detailed research methodology; and pre- and post-treatments results for the forest productivity study.

b) Technical report or journal article (depending if the results are journal-worthy) summarizing the STEMS 2 analysis. The final report has been delayed as a result of contract freezes in the early part of the year which resulted in data collection too late for the analysis and reporting to be completed. The analysis is currently underway and a technical report or journal article will be written in the coming fiscal year. The objectives of the analysis are to determine: a) how residual stand structure and corresponding light availability under 7 silvicultural systems affects natural regeneration and planted Douglas-fir and western redcedar seedling survival, browsing, and mortality over 4 years at STEMS 2; and b) how the total occurrence of windthrow and resulting seedling and regeneration mortality under 7 silvicultural systems over 4 years at STEMS 2.

Target audience/end user - Provincial, national and international science community and University/College educators – including MoFR, MoE, CFS, UBC, UVIC, SFU, Malaspina, Camosun, USDA, IUFRO.

Benefits - Communication will provide information exchange, collaboration and professional review and may attract other researchers and graduate students who could make important contributions to the on-going work there. Each installation provides a unique demonstration of seven different silvicultural systems that is ideal for scientific and student field tours.

c) Extension note summarizing the technical report. Again, this has been delayed due to the delay in the production of the technical or journal report.

Target audience and end-users: Executive and Management – includes MoFR and MoE Regional and District Managers and Executive, and Industry Woodlands Managers who manage operational staff and Policy Makers that set policies.

Operational field staff including Government/industry staff, woodlot owners, natural resource consultants, First Nations and planning staff directly involved in implementing and evaluating changes to management practices.

Benefits to executive and management - communication of the research findings will ensure the results are incorporated into policy, standards and activities that improve forest practices in BC.

Benefits to operational field staff - ensuring they understand how alternative partial cutting and silviculture treatments can lead to positive changes in ecosystem management and sustainability that will assist in their implementation.

3) Field Tours and Presentations
   a) Field Tour for Coast Region Executive. April 2008.
   b) Field Tour for Provincial Silviculturists. June 2008.
   c) The STEMS 3 cost and productivity study was summarized into a poster and presented at the Coastal Silviculture committee meeting February 25th 2010 by FP Innovation Staff (Strimbu et al 2010).
   d) The STEMS 3 cost and productivity study was also presented at the FORREX Research Chat on March 23, 2010 by FPInnovations staff. http://www.forrex.org/news/index_arch.asp

Benefits – forest researchers, managers and practitioners were given the opportunity to view and assess the structural diversity of the seven silvicultural systems and extended rotation treatments and the resulting impacts on regeneration and understory vegetation. They saw how alternative partial cutting and silviculture treatments can be used to create structural diversity that promotes biodiversity and ecosystem health, reduces environmental and visual impacts of forestry operations, while supplying high timber outputs over time. As well, a diverse audience at the Coastal Silviculture Committee meeting and through FORREX Research Chats has learned Lessons from STEMS 3 on implementing alternative silvicultural systems on the Coast during difficult markets.

4) Web site updates.

Target audience/end user – all of the above plus the general public.

Benefits to public - Communicating the results of the research of STEMS will help the public develop informed opinions about future sustainable forest management practices. Maps and trails displayed on the website will encourage the public to view the research sites themselves.

DISCUSSION

Regeneration at STEMS 2 Elk Bay, was the focus of this FIA-funded project. The site was harvested by Interfor in 2004, and planted with Douglas-fir and western redcedar in March, 2005. A technical report documents the details of the experiment and summarizes pre- and post-treatment results (de Montigny and Nigh, 2008). All seedlings within the regeneration plots were tagged and measured immediately after planting. Surveys of planted and natural regeneration under each of the silvicultural systems was conducted yearly to determine the early survival, growth, mortality, health and browsing damage over 3 years (four years since planting). As well, a vegetation survey was done in the first year to provide baseline information that will be used to assess the effects of residual stand structure on vegetation growth and competition in the future. Windthrow surveys were done annually to assess seedling and natural regeneration growth and mortality associated with fallen trees and increased light availability. The results of the surveys were summarized and reported on yearly. Hemispherical photos were completed at STEMS 2 in 2007 and were calibrated with above-canopy sensors for light availability and were used to correlate light availability to seedling and natural regeneration survival, growth and health in 2008/09. A technical report or journal article will be written to summarize the research of this project in the new fiscal year.

As well, if cost-savings were realized or additional funds were made available, then additional work to complete the post-treatment measurements at STEMS 3 was also done. STEMS 3 is the third and final replication of the STEMS experiment and is unique in that each of the treatment units consist of commercially thinned Douglas-fir. The treatment units were harvested through BC Timber Sales in 2008. Post-treatment work done with assistance of FIA and other partners included plot reestablishment, regeneration surveys, residual tree measurement, coarse woody debris surveys, soil disturbance surveys and erection of the above-canopy light sensor. Finally, a cost and productivity study was completed by FPInnovations.

STEMS is a long-term experiment and preliminary results cannot be expected to generate management implications at such a young age. However, seedling growth data will be of great interest for complex model development because there is little data for the early stages of regeneration and most light/growth studies on the coast have been performed on saplings. Measured yearly increments will be directly compared with simulated increments using least squares regression. Complex response surfaces of real and simulated values may be compared to reveal biases at high or low light or to identify confounding factors. As the dataset develops, the growth response of the conifer species will be compared to data and models tested in former studies. The data generated from this experiment are being used for calibration and validation of models for early growth and yield in complex stands and windthrow.

CONCLUSION AND MANAGEMENT IMPLICATIONS

With the conclusion of this 3 year period of FIA funding, early stand development of planted and naturally regenerated seedlings has been collected at STEMS 2. As well, the STEMS project has had critical baseline measurements taken at STEMS 3 that will be used for subsequent analysis and modeling, now and in future years.

STEMS is a long-term, multi-disciplinary, silvicultural systems experiment with a planned life of 80 years; future stand treatments and the monitoring of permanent plots will be over the course of one rotation. Given the long-term nature of the STEMS experiment and the schedule of further treatments and maintenance needed to maintain the integrity of the experiment, the post-treatment baseline information will provide current and future researchers and forest managers the necessary information to continue to derive maximum benefit from the STEMS experiment for solving current and future forest management problems. The results of this experiment will be used to improve environmental management and policies because results can be directly interpreted operationally due to the large-scale, replicated experimental design. The information will be especially relevant for forests with high multiple-use demands.

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