Montane Alternative Silvicultural Systems (MASS)

Twenty-five Year Growth of Planted and Natural Regeneration

prepared for Mosaic Forest Management by
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Summary

The Montane Alternative Silvicultural Systems (MASS) research project was established near Campbell River, B.C. from 1991–1994 to address regeneration, wildlife habitat and aesthetic concerns over clearcutting at higher elevations on Vancouver Island. This report describes work completed in 2018 that quantifies and compares the growth and survival of planted and natural conifers 25 years after harvest. Amabilis fir, western hemlock, Douglas-fir, yellow-cedar, and western redcedar were planted within a variety of overstory conditions (silvicultural systems). The systems were: Clearcut (0% retention), Patch Cut (small 1.5 ha patches removed), Green Tree (25 trees/ha retained), and Shelterwood (30% trees retained).

Among all five species compared, planted Douglas-fir trees were by far the tallest with the largest stem diameters regardless of silvicultural system. Douglas-fir height was similar in the Clearcut, Green Tree, and Patch Cut treatments (~ 13m) and just over 11m in the Shelterwood. The largest Douglas-fir stem volumes were observed in the Patch Cuts where they may have had more protected and favourable growing conditions. Trees growing within the Shelterwood were generally smaller than trees growing within the other silvicultural systems that afforded higher levels of light. Despite this, the Shelterwood offers other values such as retention of wildlife habitat and positive visual aesthetics.

The combined effects of fertilization at the time of planting and vegetation control resulted in the largest amabilis fir trees after 25 years (most pronounced in the clearcut) followed closely by vegetation control alone. Vegetation control alone appears to have had a similar effect on western hemlock as the combined fertilization at the time of planting and vegetation control treatments.

In contrast to their size, planted Douglas-fir seedlings experienced the highest rate of mortality (35–40% among systems) compared to the other planted species (amabilis fir, 10–23%; western hemlock, 11–30%; western redcedar, 9–23%; and yellow-cedar, 18–19%). Mortality of the natural amabilis fir and western hemlock ranged from 15–37% among silvicultural systems. There was greater mortality for planted hemlock in the Clearcut over the past 20 years compared to other systems, and greater mortality for natural amabilis fir in the Shelterwood over the past 10 years.

Natural amabilis fir performed the best in terms of height growth within the Clearcut and Patch Cuts. One rationale for establishing the MASS project in the CWHmm2 biogeoclimatic variant at these elevations was a perceived “growth check” observed in amabilis fir in young plantations. These results suggest that growth check does not persist after 15 years. Natural western hemlock heights after 25 years were tallest in the Clearcut. The growth of western hemlock also began to accelerate more quickly after 15 years.

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Introduction and Experimental Design

The MASS study area is located in Mosaic Forest Management's Iron River Operation south of Campbell River. The site is a gently-sloping, northerly aspect at 750 m to 850 m elevation within the Montane Moist Maritime Coastal Western Hemlock (CWHmm2) biogeoclimatic variant. The old-growth forest consisted of predominantly western hemlock (*Tsuga heterophylla*) and amabilis fir (*Abies amabilis*), with varying amounts of western redcedar (*Thuja plicata*) and yellow-cedar (*Chamaecyparis nootkatensis*).

The overall experiment design includes silvicultural systems representing a range of over-story removal:

Clearcut (CC): A 69-ha area was harvested over a two-year period with two adjacent clearcuts to provide a large clearcut for comparison to alternative systems.

Patch Cut (PC): Small cut-blocks (1.5 ha to 2 ha) were designed with alternating leave-strips so that regeneration is within two tree lengths of an edge.

Green Tree Retention (GT): Also referred to as dispersed retention, 25 trees/ha were left uniformly distributed to enhance the structural diversity of future stands for wildlife and aesthetics.

Shelterwood (SW): Trees representing the entire stand profile and 30% of the basal area (200 sph over 17.5 cm DBH) were left throughout the stand. This system provides protection for regeneration against snow, wind and temperature extremes, and enhances the structural diversity of future stands for wildlife and aesthetic values.

There are three replicates of each of the clearcut alternatives which are compared to three portions of the clearcut and an adjacent, uncut old growth forest (Figure 1).

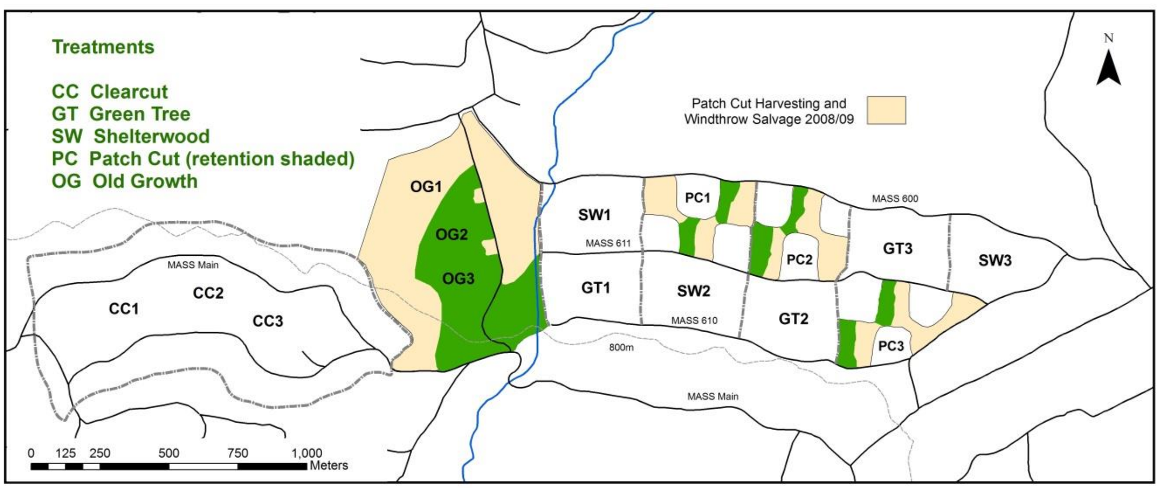

Figure 1. MASS study area layout.

Two studies were established to monitor the growth and survival of <u>planted</u> conifers: the main study comparing western hemlock (Hw) and amabilis fir (Ba), and a secondary study comparing three other species – Douglas-fir (Fd), western redcedar (Cw) and yellow-cedar (Cy). A third study was established to evaluate the growth and survival of natural Ba and Hw. The three studies are described in more detail below.

Study #1
The study area was harvested in 1992 (Clearcut) and 1993. Amabilis fir and western hemlock were planted in each of the four treatment areas (CC, PC, GT, and SW) in the spring of 1994. Four post-planting treatments were applied for comparison: control (C), fertilization (F), vegetation control (H), vegetation control combined with fertilization (FH) administered at the time of planting (Figure 2).

- Seedlings planted in the fertilizer treatment plots (F) received a one-time application at the time of planting of 24 g of slow-release fertilizer (Nutricote 16-10-10, 180-day formulation).
- The vegetation control plots (H) received 5 applications of glyphosate applied by means of backpack sprayers between 1994 and 1997. Woody vegetation (primarily *Vaccinium* species) was also mechanically cut and removed from these plots.
- The FH treatment plots received both of the fertilizer and vegetation control treatments described above.
- Control (C) plots were not treated.

The number of seedlings planted in each study is given in Table 1.

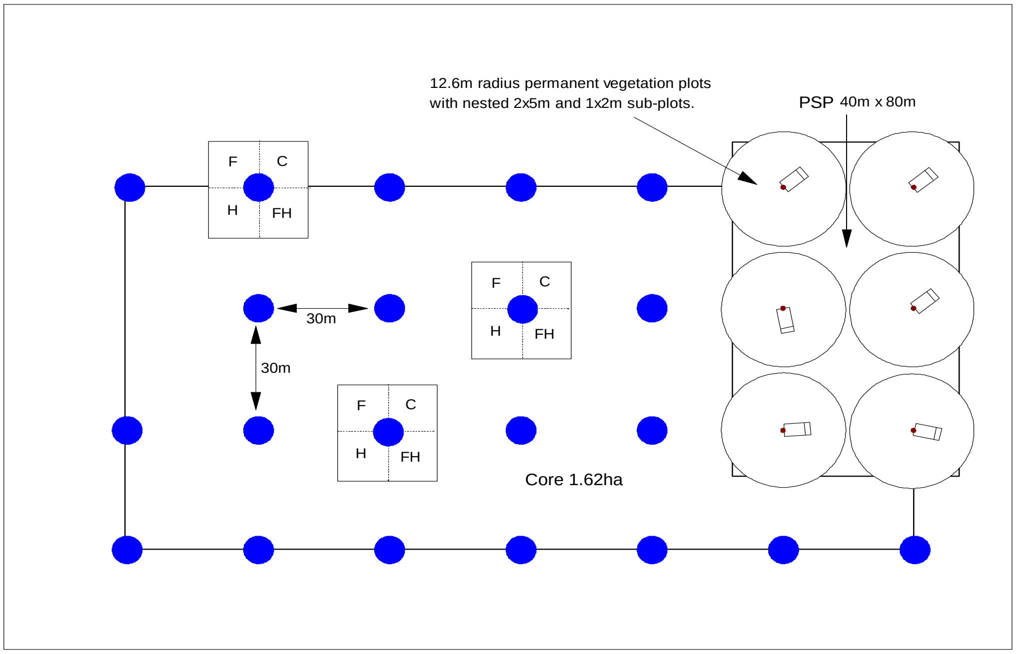

Figure 2. Sample plot layout for planted tree growth and natural regeneration studies. Blue circles represent 30x30m grid points from which 12 were randomly selected for planted tree plots. Six trees (3 Ba, 3 Hw) were planted in each sub-treatment (F, C, H, FH); 5 plots were used for destructive sampling in early years for seedling dry weights and physiological measurements, leaving 7 plots for long-term measurement. Natural Ba and Hw (3 of each species) were tagged and measured within or near the vegetation subplots (rectangles within the larger circles) on the growth and yield Permanent Sample Plot (PSP). Douglas-fir, western redcedar and yellow-cedar were planted within a 22m wide corridor surrounding the central “core” of each replicate illustrated in the diagram.

Study #2
Douglas-fir, yellow-cedar, and western redcedar were planted within each of the four treatment areas (CC, PC, GT, and SW) to compare their growth and survival with the planted Ba and Hw trees in Study #1. These seedlings did not receive any treatment at the time of planting.

Study #3
Naturally occurring Hw and Ba trees and seedlings were tagged and their growth and survival was assessed over time for comparison with the planted seedlings.

Study		Total number of trees by species					**Total Establ.**	Surviving at 15 yrs	Surviving at 25 yrs
		Ba	Hw	Cw	Cy	Fd			
1	Planted – "Arnott-Dunsworth"	1008	1008				**2016**	1729	1649
2	Planted – "Racetracks"			600	600	600	**1800**	1402	1335
3	Natural Regen	270	270				**540**	394	321
	Total	1278	1278	600	600	600	**4356**	3525	3305

Table 1. Planted and natural trees measured in the three regeneration studies at MASS.

Results and Discussion

1.0 Species Comparison - Growth

After twenty-five years, Douglas-fir trees outperformed all other species (Figure 3). They were the tallest with the largest stem diameters.

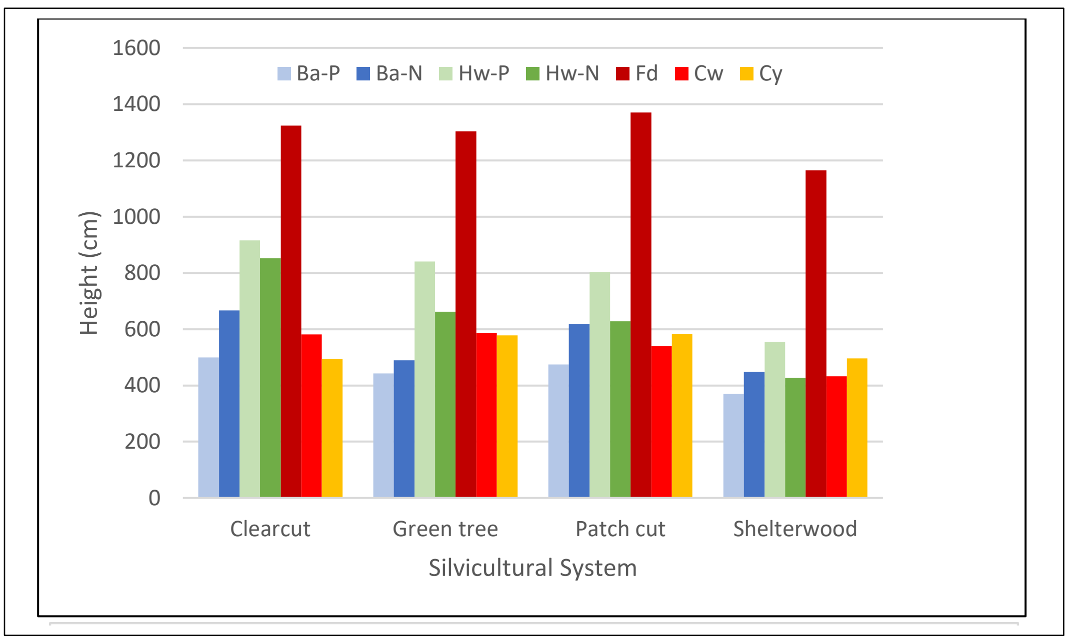

Figure 3. Height by silvicultural treatment for all species, planted (P) and natural (N) regeneration.

The smallest Douglas-fir volumes were observed in the shelterwood, presumably where light was a limiting factor affecting growth (Figure 4). The highest rate of crown damage (snow breakage) was observed in the Douglas-fir, particularly in the clearcut. Total stem volume of natural Ba exceeded planted Ba for all systems; however, total stem volume of planted Hw exceeded natural Hw for all systems. There was no difference in seed source between planted Ba and Hw. Although genetics may play a role, the difference between Ba and Hw appears to be related to the ability of planted trees to establish root systems and acclimate to the site. Planted Cw and Cy were consistently slower growers (similar to natural and planted amabilis fir).

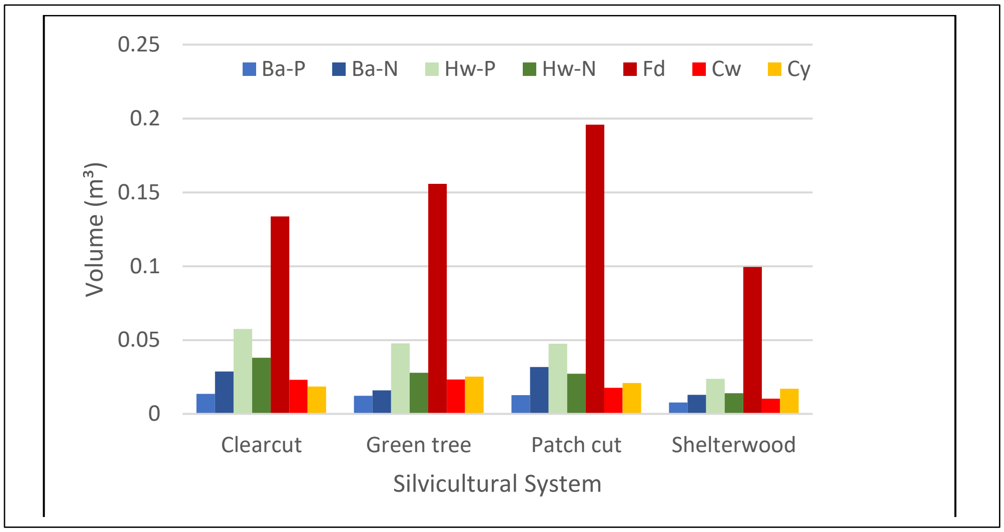

Figure 4. Volume by silvicultural treatment for all species, planted (P) and natural (N) regeneration.

2.0 Effects of Fertilization and Vegetation Control

The combined effects of fertilization at the time of planting and vegetation control (FH) resulted in the largest amabilis fir trees after twenty-five years followed closely by vegetation control alone. The FH treatments were most effective for increasing amabilis fir growth in the clearcut.

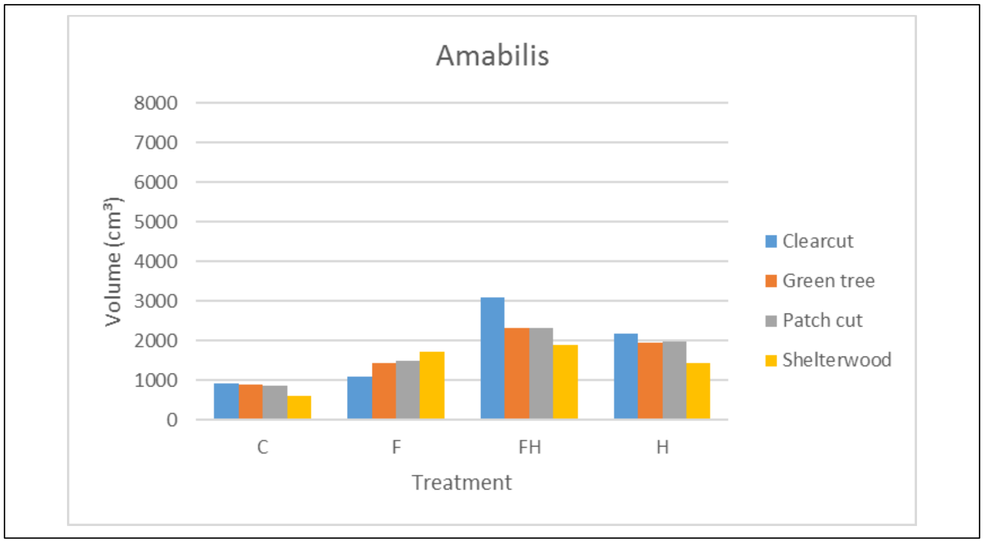

Figure 5. Volume of amabilis fir by silvicultural system and sub-treatment (C=Control, F=Fertilization, H=Herbicide, FH=Fertilization and Herbicide).

Vegetation control (H) alone appears to have had a similar effect on western hemlock as the combined fertilization at time of planting and vegetation control treatments (FH). Vegetation control alone had the greatest effect on western hemlock in the clearcut.

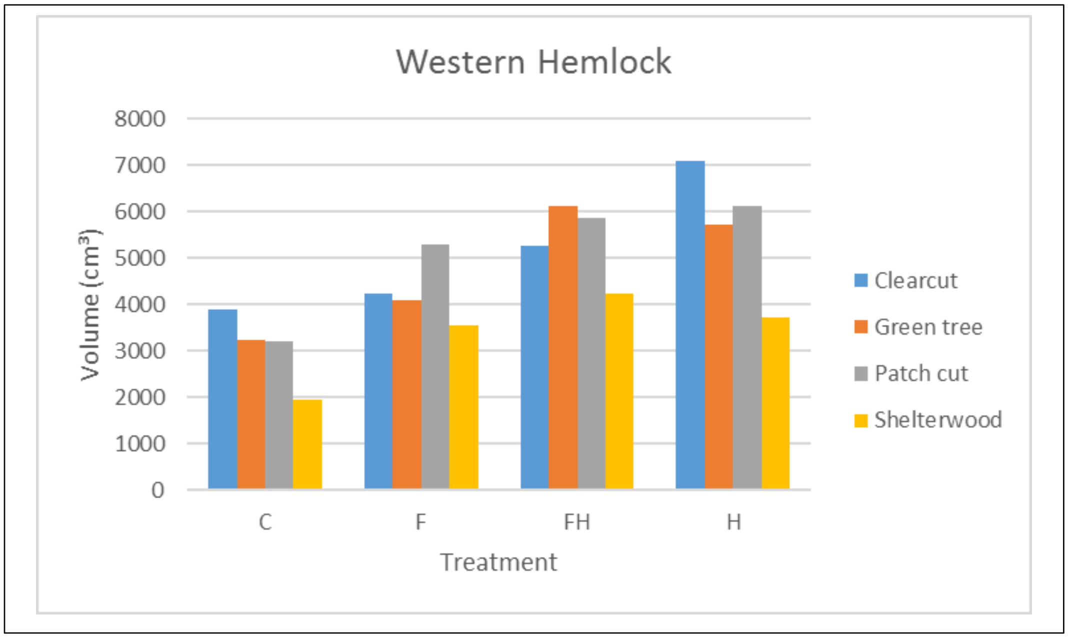

Figure 6. Volume of western hemlock by silvicultural system and sub-treatment (C=Control, F=Fertilization, H=Herbicide, FH=Fertilization and Herbicide).

3.0 Survival

In contrast to their exceptional growth performance, planted Douglas-fir seedlings had the highest rate of mortality (35-40%) while planted western redcedar and yellow-cedar had the lowest rates of mortality (Figure 7). Western redcedar had greater variability in survival among silvicultural systems than yellow-cedar or Douglas-fir.

There was considerable variation in survival between planted and natural amabilis fir and western hemlock as well as among silvicultural systems (Figures 8 and 9). The highest mortality (35%+) was for natural western hemlock in the Shelterwood and Green Tree systems, and natural amabilis fir in the Shelterwood. Planted hemlock mortality was highest in the Clearcut (30%), where it increased substantially over the past 20 years compared to other systems after tracking at a similar rate in the first 5 years after planting. Except for this anomaly, mortality for both planted Ba and Hw was highest in the Shelterwood.

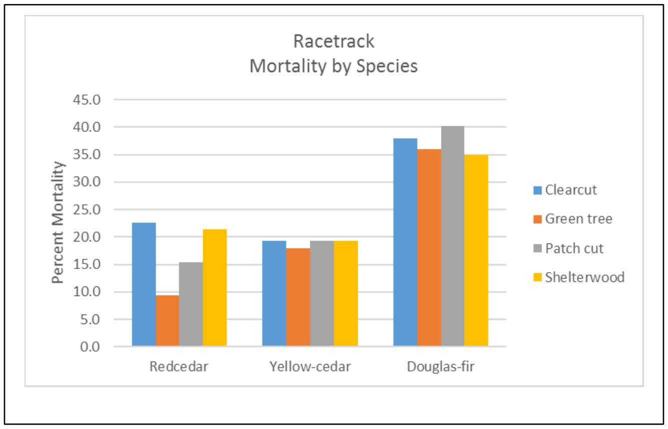

Figure 7. Total mortality by species at 25 years for supplemental plantings of western redcedar, yellow-cedar and Douglas-fir at MASS.

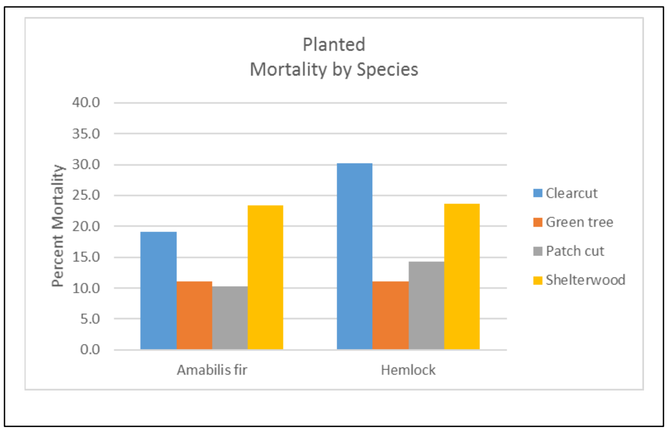

Figure 8. Total mortality by species at 25 years for planted amabilis fir and western hemlock at MASS.

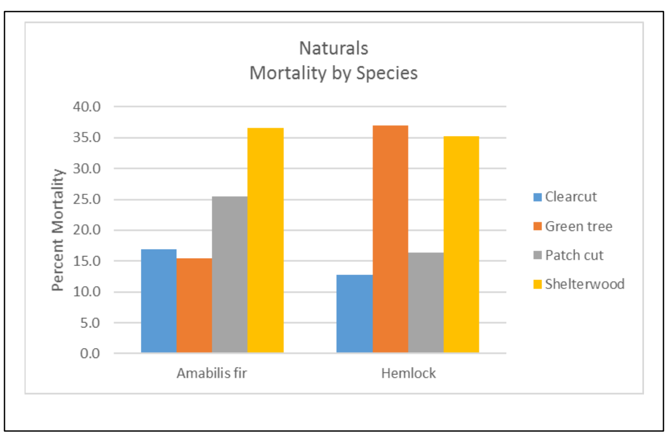

Figure 9. Total mortality by species at 25 years for natural amabilis fir and western hemlock at MASS.

4.0 Natural Regeneration

Natural amabilis fir performed similarly in terms of height growth within the Clearcut and Patch Cuts (Figure 10). Twenty-five year heights were also similar (and somewhat shorter) within the Green Tree and Shelterwood. One rationale for establishing the MASS project in the CWHmm2 biogeoclimatic variant at these elevations was a perceived "growth check" observed in amabilis fir in young plantations. These data suggest that growth check may not persist after 15 years.

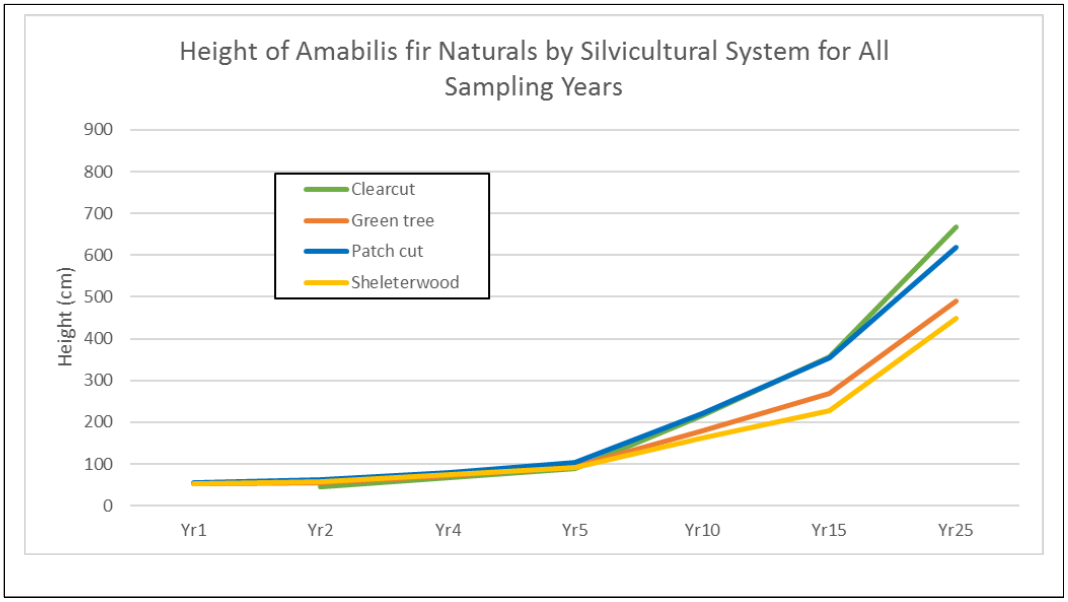

Figure 10. Height of amabilis fir naturals by silvicultural system for all sampling years.

Natural western hemlock heights after 25 years were tallest in the Clearcut, followed by the Green Tree and Patch Cuts clustered together, and were shortest in the Shelterwood (Figure 11). Growth of western hemlock also began to accelerate more quickly after 15 years.

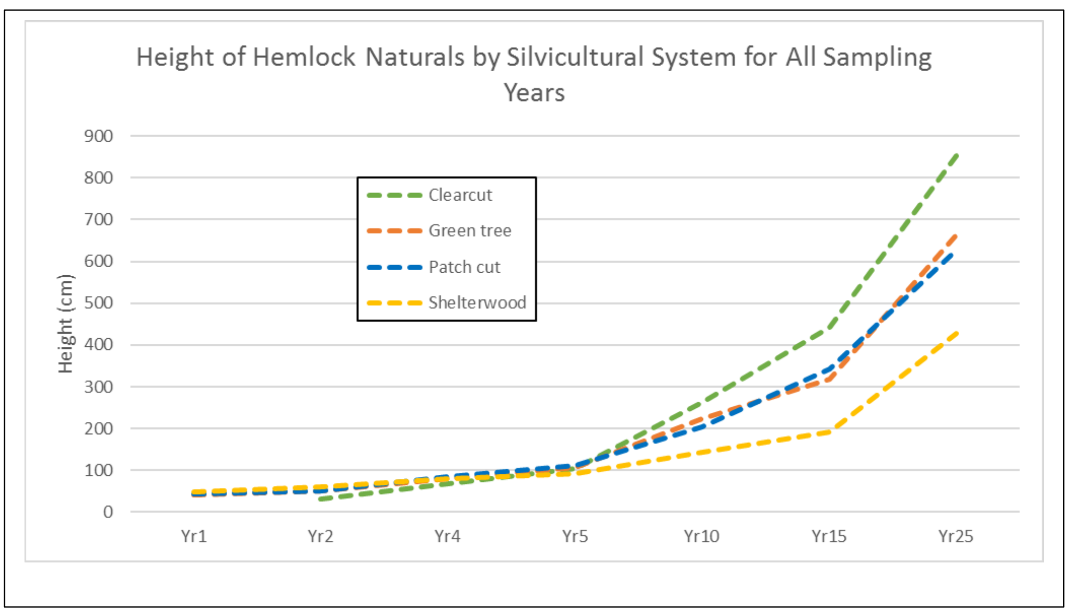

Figure 11. Height of western hemlock naturals by silvicultural system for all sampling years.

Conclusions

The following conclusions have been extracted and updated from the 15-year report (Beese et al. 2009).

The growth of planted western hemlock (Hw) and amabilis fir (Ba) after 15 years was reduced by the dispersed tree retention in the shelterwood (SW) in relation to the other silvicultural systems tested at MASS. Survival and growth of both species was generally not significantly different from clearcutting (CC) in the small patch cut openings (PC) or the low-density “green tree” (GT) retention system. Low understory light seemed to be the overriding factor responsible for lower growth in the SW, where cumulative growing season irradiance was well below those in the other silvicultural systems (Benton 2004). Sixty percent shade, a level that is exceeded in approximately one-third of the SW understory, has been reported to reduce biomass production in both Hw and Ba (Mitchell and Arnott 1995).

The response to fertilizer alone, applied only once at the time of planting, was most pronounced early in the study (Mitchell et al 2004), but was diminished after ten years in both species with some exceptions. The vegetation control treatment was done repeatedly over a four-year period so it is not surprising that its impact persisted longer than the fertilization treatment. After 25 years, there were significant improvements in growth for Hw and Ba with vegetation control alone (H) or in combination with fertilization (HF). We attribute the growth increase from vegetation control to increased availability of nutrients as well as available light for microsites where regeneration was overtopped by surrounding vegetation in the first five to seven years after planting. At MASS, below-ground competition is primarily for nutrients; moisture is generally not a limiting factor (Mitchell *et al.* 2004), although we suspect that severe droughts in recent years have contributed to increased mortality.

The supplemental planting of Douglas-fir (Fd), western redcedar (Cw) and yellow-cedar (Yc) at MASS showed that these species had similar relative growth responses among silvicultural systems; however, their absolute growth rates differed from the hemlock and amabilis fir. Although Douglas-fir growth exceeded all other species, overall survival was significantly less than other species. Another concern with use of Fd at the upper end of its elevation range is the potential for snow breakage, although in a study comparing conifers in the montane CWH and subalpine MH biogeoclimatic units form defects from snow damage were an equal problem for Hw, Cw and Fd, and an even greater problem for Yc (Arnott *et al.* 1995). Our data support this finding with a greater incidence of multiple-tops in Yc (13%) compared to Fd and Cw (8%). Our results suggest that a warming climate had made the lower elevations of the CWHmm2 variant suitable for Fd. Growth of both Cw and Yc was substantially less than planted Hw but better than planted Ba. Yellow-cedar growth was typically better than western redcedar. This can be attributed to the fact that the MASS site is in the transitional elevation range where Cw is gradually replaced by Yc (i.e., Cw is at the upper limit of its range) in the montane CWHmm2 variant and MH zone (Green and Klinka 1994).

An unexpected result was the difference in growth between planted and natural hemlock and amabilis fir. Total stem volume of natural Ba exceeded planted Ba for all systems; however, total stem volume of planted Hw exceeded natural Hw for all systems. Morphological and physiological characteristics of the planting stock of both species do not explain the difference in planted tree performance between the species. There was no difference in seed source between planted Ba and Hw; both were from 750m elevation in the Franklin River area of southern Vancouver Island (unpublished establishment records). Although this suggests no provenance factor between the planted Hw and Ba, it does not eliminate the possibility that the genetic potential of planted and natural seedlings differed. Although genetics may play a role, the difference between Ba and Hw appear to be related to the ability of planted trees to establish root systems and acclimate to the site. Advanced growth natural regeneration had the advantage of a larger root system when we began our growth measurements. Apparently, this was more important for Ba than Hw, possibly because of higher nutrient requirements of Ba compared to Hw .

No single silvicultural system will meet all objectives; consequently, results from MASS are not meant to select a single “best” practice, but to improve our ability to predict the consequences of alternatives so that systems can be chosen to meet specific goals.

Acknowledgments

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