Hardwood Silviculture Cooperative Annual Report 2017

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Contents

- Highlights 2017……………………………………………………………..2
- History of the HSC………………………………………………………….3
- Red Alder Stand Management Study……………………………………….4
- Current HSC Activities
    - An Alder Day in the Woods……………………………………………11
    - Red Alder Taper Data Collection………………………………………19
- Research Results
    - Alder/cedar Species Mixtures…………………………………………..21
- Outreach and Education
    - Red Alder Silviculture Workshop………………………………………46
    - Forest Owners Field Day………………………………………………..47
    - Clackamas Tree School…………………………………………………48
- Future Direction 2018………………………………………………………...49
- Appendix 1
    - HSC 2016 Committee Meeting Minutes………………………………..50
- Appendix 2
    - HSC Financial Support 2017……………………………………………53

Hardwood Silviculture Cooperative

Highlights of 2017

- Two more 27 year measurements were collected on the Type 2 installations (variable-density red alder plantation), bringing the total to 3 of the 26 installations with 27 year data.
- Three more 22 year measurements were collected on the Type 2 installations, bringing the total to 22 of the 26 installations with 22 year data.
- Twenty of the 26 Type 2 installations have had all treatments completed.
- One more 22 year measurement was collected on the Type 3 installations (red alder/Douglas-fir species mixtures), bringing the total to 5 of the 7 installations with 22 year data.
- Additional field data on tree taper was collected:
    - Nine trees from the 22 year-old Mt. Gauldy (SNF) Type 2 installation.
    - Sixteen trees from a 45 year-old mixed-species, natural stand in the OR Coast Range.
- Data was collected from a 26 year-old mixed red alder/red cedar replacement series experiment near Mt. Vernon, WA. The preliminary results are presented here.
- The HSC contributed to, and presented results at, a guided tour of red alder plantations organized by the Washington Hardwood Commission (WHC). "An Alder Day in the Woods" was held on Weyerhaeuser property and led by (now retired) Weyerhaeuser research forester Alex Dobkowski. The tour covered most aspects of intensively managed red alder plantation activities including site selection, planting stock, soil site index vs. expressed site index, pre-commercial thinning, commercial thinning, etc.
- Efforts were undertaken by the HSC to determine the feasibility, timing, and funding of a project to update RAP-ORGANON with additional, older tree data.
- The HSC participated in three continuing education and outreach events: a DNR red alder silviculture workshop, Clackamas Tree School, and the WA Farm Forestry Association (WFFA) Forest Owners Field Day.

History of the HSC

The Hardwood Silviculture Cooperative (HSC) is a multi-faceted research and education program focused on the silviculture of red alder (*Alnus rubra*) and mixes of red alder and Douglas-fir (*Pseudotsuga menziesii*) in the Pacific Northwest. The goal of the HSC is improving the understanding, management, and production of red alder. The activities of the HSC have already resulted in significant gains in understanding of regeneration and stand management, and have highlighted the potential of red alder to contribute to both economic and ecological forest management objectives.

The HSC, begun in 1988, is a combination of industry and both federal and state agency members, each with their own reasons for pursuing red alder management. For instance, some want to grow red alder for high-quality saw logs, while others want to manage red alder as a component of bio-diversity. What members have in common is that they all want to grow red alder to meet their specific objectives. Members invest in many ways to make the HSC a success. They provide direction and funds to administer the Cooperative. They provide the land for research sites and the field crews for planting, thinning, and taking growth measurements.

The HSC's highest priority is to understand the response of red alder to intensive management. To accomplish this, the HSC has installed 26 variable-density plantations extending from Coos Bay, Oregon to Vancouver Island, British Columbia. The majority of plantations are located in the Coast Range, with a few in the Cascade Range. The plantation distribution covers a wide range of geographic conditions and site qualities. At each site, cooperators planted large blocks of red alder at densities of 100, 230, 525, and 1200 trees per acre. Each block is subdivided into several treatment plots covering a range of thinning and pruning options (twelve total treatments per site).

In addition to the 26 variable-density plantations, the HSC has related studies in naturally regenerated stands. Young stands (less than 15 years old) of naturally regenerated red alder, 5 to 10 acres in size, were pursued as a means of short-cutting some of the lag time before meaningful thinning results could be obtained from the variable-density plantations. It came as a surprise to find only four naturally regenerated stands of the right age and size available in the entire Pacific Northwest.

The HSC has also established seven mixed species plantations of red alder and Douglas-fir. They are located on land designated as Douglas-fir site class III or below. Each plantation is planted with 300 trees per acre with five proportions of the two species. The site layout is designed to look at the interactions between the two species. We are finding that in low proportions and when soil nitrogen is limited, red alder may improve the growth of Douglas-fir. This improvement is due to the nitrogen fixing ability of red alder. The management challenge is to find the right proportion of the two species through time to maintain a beneficial relationship.

Since the HSC was established, we have learned a great deal about seed zone transfer, seedling propagation, stocking guidelines, identification of sites appropriate for red alder, and the effects of spacing on early tree growth (see the HSC web-page http://hsc.forestry.oregonstate.edu for more information). Furthermore, the data set is now complete enough to begin analyzing the growth response of red alder after thinning and/or pruning. Our ultimate goal is a better understanding of the effects of stand density management on red alder growth and yield, and wood quality and to develop red alder growth and yield models.

The HSC red alder stand management studies are well designed and replicated on a scale rarely attempted in forestry. Over the next 20 years, we will harvest much from our investment. Our data set on growth of managed stands will make red alder one of the better-understood forest trees of the Pacific Northwest.

Red Alder Stand Management Study

The Red Alder Stand Management Study is divided into three specific types of installations. Study installations are predominately located in the coastal mountain ranges of the Pacific Northwest from Coos Bay, Oregon to Vancouver Island, British Columbia (Figure 1).

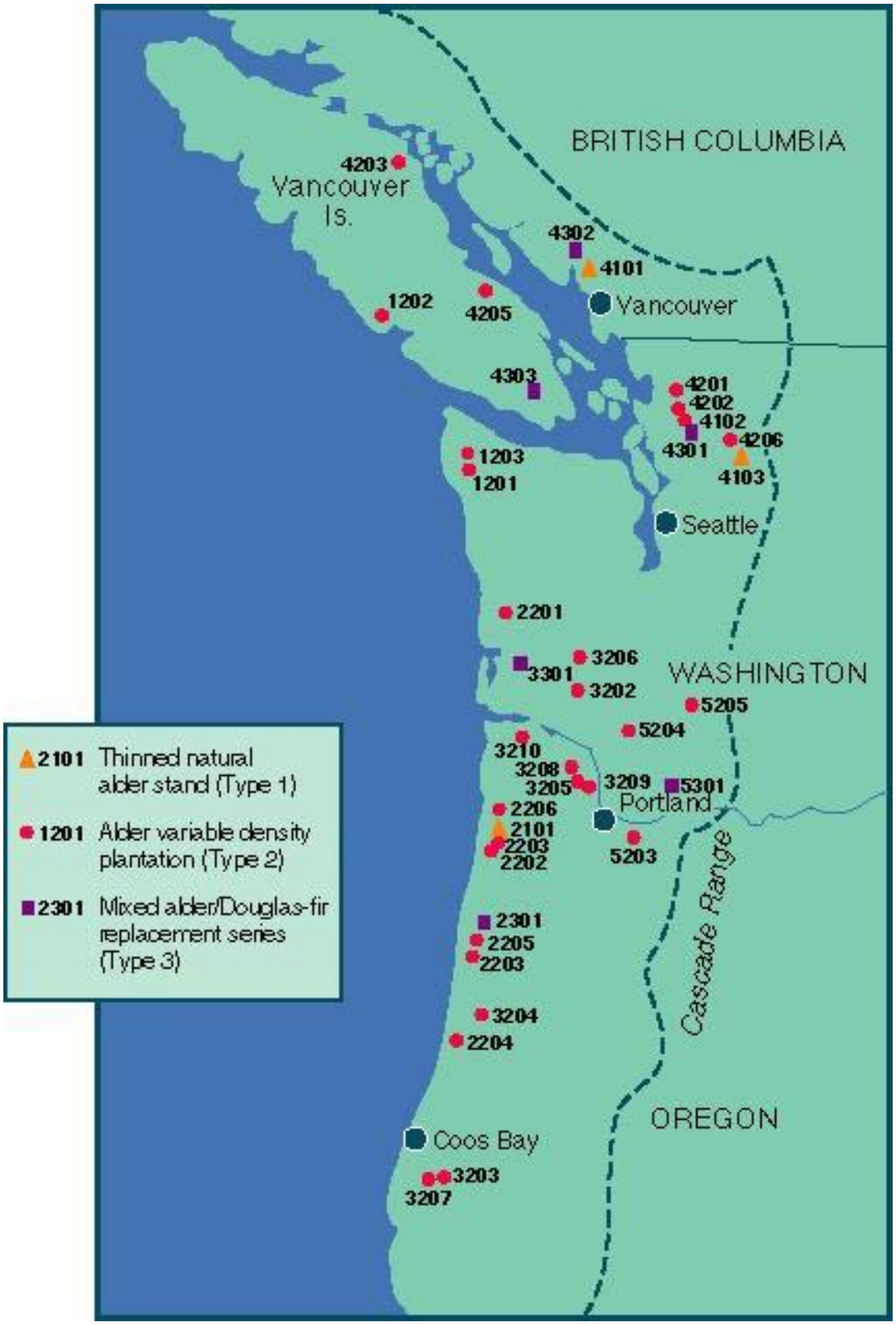


Figure 1. Location of installations for the Red Alder Stand Management Study.

The three types of study installations are as follows:

- Type 1 is a natural red alder stand thinned to 230 and 525 trees per acre. There are four Type 1 installations.
- Type 2 is a variable-density red alder plantation. At each site, red alder is planted in large blocks at densities of approximately 100, 230, 525, and 1200 trees per acre. Each block is subdivided into several thinning and pruning treatments. There are twenty-six Type 2 installations.
- Type 3 is a mixed species plantation of red alder and Douglas-fir. Each site is planted to 300 trees per acre with five proportions of the two species. There are seven Type 3 installations.

The primary focus of the Red Alder Stand Management study continues to be the Type 2 variable-density plantations. Type 2 installations are distributed across a matrix of five ecological regions and three site quality classes (Table 1).

Table 1. Matrix of Type 2 installations. Each installation identified by number, ownership, and year planted.

	Site Quality		
Region	Low SI50 :23-27 M SI20 :14-17 M	Medium SI50 :28-32 M SI20 :18-20 M	High SI50 :33+ M SI20 :21+ M
1) Sitka Spruce North	X	1201 DNR ‘91	1202 BCMin ‘94 1203 DNR ‘96
2) Sitka Spruce South	2202 SNF ‘91 2206 SNF ‘95	2203 ANE ‘92 2204 SNF ‘94	2201 WHC ‘90 2205 ANE ‘94
3) Coast Range	3204 SNF ‘92 3209 BLM ‘95	3202 WHC ‘90 3205 ODF ‘92 3207 BLM ‘94 3208 ODF ‘97	3203 CAM '92 3206 WHC '93 3210 OSU ‘97
4) North Cascades	4205 BCMin ‘94	4202 GYN ‘90 4203 BCMin ‘93 4206 DNR ‘95	4201 GYN ‘89
5) South Cascades	5205 GPNF ‘97	5203 BLM ‘92 5204 WHC ‘93	X

With each passing year, more and more treatments are applied and more data is collected. Tables 2, 3, and 4 describe the data collection schedules for the three installation types. The shaded areas of the tables indicate the activities that have been completed and illustrate the tremendous accomplishments of the HSC to date.

Table 2a. Data Collection Schedule for Type 2 Installations. Shaded areas indicate completed activities.

TYPE 2	**GYN**	**WHC**	**WHC**	**GYN**	**DNR**	**SNF**	**NWH**	**NWH**	**SNF**	**ODF**	**BLM**	**WHC**	**BCmin**
Site Number	**4201**	**2201**	**3202**	**4202**	**1201**	**2202**	**2203**	**3203**	**3204**	**3205**	**5203**	**3206**	**4203**
Site Name	**Humphrey**	**John's R.**	**Ryderwood**	**Clear Lake**	**LaPush**	**Pollard**	**Pioneer**	**Sitkum**	**Keller-Grass**	**Shamu**	**Thompson**	**Blue Mtn.**	**Mohun Ck.**
Year Planted	1989	1990	1990	1990	1991	1991	1992	1992	1992	1992	1992	1993	1993
1st yr Regen	1989	1990	1990	1990	1991	1991	1992	1992	1992	1992	1992	1993	1993
2nd yr Regen	1990	1991	1991	1991	1992	1992	1993	1993	1993	1993	1993	1994	1994
Plot Installation	1991	1992	1992	1992	1993	1993	1994	1994	1994	1994	1994	1995	1995
3rd yr Measure	1991	1992	1992	1992	1993	1993	1994	1994	1994	1994	1994	1995	1995
3-5 yr Thin	1992	1995	1995	1993	1995	1995	1996	1997	1996	1996	1995	1997	1997
Prune Lift 1 6ft	1994	1995	1995	1995	1995	1995	1996	1997	1996	1996	1995	1997	1997
6th yr Measure	1994	1995	1995	1995	1996	1996	1997	1997	1997	1997	1997	1998	1998
15-20' HLC Thin	1994	NA	1998	1995	1998	NA	1999	2000	2000	1999	1999	2001	NA
Prune Lift 2 12ft	1994	2001	1998	1995	2001	1999	1999	2000	1998	1999	1999	2001	2001
9th yr Measure	1997	1998	1998	1998	1999	1999	2000	2000	2000	2000	2000	2001	2001
Prune Lift 3 18ft	1997	2009	2001	1998	2007	2002	2003	2000	2008	2003	2003	2001	2006
12th yr Measure	2000	2001	2001	2001	2002	2002	2003	2003	2003	2003	2003	2004	2004
30-32' HLC Thin	2000	NA	NA	2001	2010	2007	2008	2003	NA	2006	2008	2006	2009
Prune Lift 4 22 ft	2000	NA	2001	2001	2017	2007	2008	2003	2013	2006	2008	2004	2009
17th yr Measure	2005	2006	2006	2006	2007	2007	2008	2008	2008	2008	2008	2009	2009
22nd yr Measure	2010	2011	2011	2011	2012	2012	2013	2013	2013	2013	2013	2014	2014
27th yr Measure	2015	2016	2016	2016	2017	2017	2018	2018	2018	2018	2018	2019	2019
32nd yr Measure	2020	2021	2021	2021	2022	2022	2023	2023	2023	2023	2023	2024	2024

Table 2b. Data Collection Schedule for Type 2 Installations. Shaded areas indicate completed activities.

TYPE 2	WHC	BCmin	SNF	NWH	BLM	BCmin	SNF	BLM	DNR	DNR	ODF	OSU	GPNF
Site Number	5204	1202	2204	2205	3207	4205	2206	3209	4206	1203	3208	3210	5205
Site Name	Hemlock Ck.	Lucky Ck.	Cape Mtn.	Siletz	Dora	French Ck.	Mt. Gauldy	Scappoose	Darrington	Maxfield	Weebe	Wrongway	Tongue Mtn.
Year Planted	1993	1994	1994	1994	1994	1994	1995	1995	1995	1996	1997	1997	1997
1st yr Regen	1993	1994	1994	1994	1994	1994	1995	1995	1995	1996	1997	1997	1997
2nd yr Regen	1994	1995	1995	1995	1995	1995	1996	1996	1996	1997	1998	1998	1997
Plot Installation	1995	1996	1996	1996	1995	1995	1996	1997	1996	1997	1999	1999	1999
3rd yr Measure	1995	1996	1996	1996	1996	1996	1997	1997	1997	1998	1999	1999	1999
3-5 yr Thin	1997	1998	1998	1998	1998	1998	2000	1999	NA	2001	2002	NA	NA
Prune Lift 16ft	NA	1998	1998	1998	NA	1998	2000	1999	1999	2001	2002	2002	NA
6th yr Measure	1998	1999	1999	1999	1999	1999	2000	2000	2000	2001	2002	2002	2002
15-20' HLC Thin	2001	NA	2005	NA	2002/17	2002	NA	NA	NA	NA	NA	NA	NA
Prune Lift 2 12ft	NA	2005	2002	2002	NA	2002	2003	2003	2001	2004	2008	2005	NA
9th yr Measure	2001	2002	2002	2002	2002	2002	2003	2003	2003	2004	2005	2005	2005
Prune Lift 3 18ft	NA	2015	2012	2010	NA	2005	2011	2009	2003	2010	2011	2010	NA
12th yr Measure	2004	2005	2005	2005	2005	2005	2006	2006	2006	2007	2008	2008	2008
30-32' HLC Thin	2006	NA	2017	2010	NA	NA	2011	2009	2011	2010	2011	2010	NA
Prune Lift 4 22 ft	NA	NA	2017	2020	NA	2013	2016	2009	2006	2017	2013	2013	NA
17th yr Measure	2009	2010	2010	2010	2010	2010	2011	2011	2011	2012	2013	2013	2013
22nd yr Measure	2014	2015	2015	2015	2015	2015	2016	2016	2016	2017	2018	2018	2018
27th yr Measure	2019	2020	2020	2020	2020	2020	2021	2021	2021	2022	2023	2023	2023
32nd yr Measure	2024	2025	2025	2025	2025	2025	2026	2026	2026	2027	2028	2028	2028

Table 3. Data Collection Schedule for Type 1 Installations. Shaded areas indicate complete

TYPE 1	BCmin	SNF	DNR	MBSNF
Site Number	**4101**	**2101**	**4102**	**4103**
Site Name	**Sechelt**	**Battle Saddle**	**Janicki**	**Sauk River**
Plot Installation	1989	1990	1991	1994
1st yr Measurement	1989	1990	1991	1994
3rd yr Measurement	1992	1993	1994	1997
6th yr Measurement	1995	1996	1997	2000
9th yr Measurement	1998	1999	2000	2003
14th yr Measurement	2003	2004	2005	2008
19th yr Measurement	2008	2009	2010	2013

Table 4. Data Collection Schedule for Type 3 Installations. Shaded areas indicate completed activities.

Owner	BCmin	NWH	GYN	BCmin	DNR	SNF	GPNF
Site Number	**4302**	**2301**	**4301**	**4303**	**3301**	**2302**	**5301**
Site Name	**East Wilson**	**Monroe-Indian**	**Turner Creek**	**Holt Creek**	**Menlo**	**Cedar Hebo**	**Puget**
Year Planted	1992	1994	1994	1994	1995	1996	1997
1st yr Regen Survey	1992	1994	1994	1994	1995	1996	1997
2nd yr Regen Survey	1993	1995	1995	1995	1996	1997	1998
Plot Installation	1993	1995	1995	1995	1997	1998	1999
3rd yr Measurement	1994	1996	1996	1996	1997	1998	1999
6th yr Measurement	1997	1999	1999	1999	2000	2001	2002
9th yr Measurement	2000	2002	2002	2002	2003	2004	2005
12th yr Measurement	2003	2005	2005	2005	2006	2007	2008
17th yr Measurement	2008	2010	2010	2010	2011	2012	2013
22nd yr Measurement	2013	2015	2015	2015	2016	2017	2018
27th yr Measurement	2018	2020	2020	2020	2021	2022	2023
32nd yr Measurement	2023	2025	2025	2025	2026	2027	2028

The Winter 2016/17 measurements consisted of six installations requiring field work (Table 5). Three sites had their 22nd year measurement (Mt. Gauldy, Scappoose, Darrington) and two sites had their 27th year measurement (Ryderwood, Clear Lake Hill). One Type 3 installation (Menlo) had its 22nd year measurement. In addition, the Type 2 site, Mt. Gauldy had its fourth and final pruning lift. There were no orphaned sites requiring fieldwork so scheduling and completing these measurements went smoothly. Taper measurements were collected at the Mt. Gauldy site as well as at a 45 year-old stand in the Oregon Coast Range.

Table 5. Hardwood Silviculture Cooperative Field Activities, Fall 2016-Spring 2017

Type	Activity	Installation	Cooperator
Type 1	Completed		
Type 2	4th Pruning Lift	2206	SNF-Mt. Gauldy
	22yr Measure	2206	SNF- Mt. Gauldy
		3209	BLM- Scappoose
		4206	DNR- Darrington
	27yr Measure	3202	WHC- Ryderwood
		4202	GYN- Clear Lake Hill
Type 3	22yr Measure	3301	DNR- Menlo

So, in the big picture:

- All scheduled measurements for the four Type 1 installations are completed.
- Twenty two of the twenty-six Type 2 installations have had their 22^{nd} year measurement.
- There are three Type 2 sites now having their 27^{th} year measurement completed.
- Twenty one of the twenty-six Type 2 installations have all treatments completed.
- Five of the seven Type 3 installations have had their 22nd year measurement.

This coming field season (Winter 2017/18) will be a busy year (Table 6). Two more of the oldest HSC sites (LaPush and Pollard Alder) will have their 27^{th} year measurement. One Type 2 installation (Maxfield) and one Type 3 installation (Cedar Hebo) will need their 22^{nd} year measurement. In addition to the above measurements, two installations will require thinning (Dora and Cape Mtn.) and three installations are due for the 4^{th} and final pruning lift (LaPush, Cape Mtn., and Maxfield). Luckily, there are no orphaned sites due for measurement or treatment.

Table 6. Hardwood Silviculture Cooperative Field Activities, Fall 2017-Spring 2018

Type	Activity	Installation	Cooperator
Type 1	Completed		
Type 2	4^{th} Pruning Lift	1201	DNR- LaPush
		2204	SNF- Cape Mtn.
		1203	DNR- Maxfield
	15-20ft HLC Thin	3207	BLM- Dora
	30ft HLC Thin	2204	SNF- Cape Mtn.
	22yr Measure	1203	DNR- Maxfield
	27yr Measure	1201	DNR- LaPush
		2202	SNF- Pollard Alder
Type 3	22yr Measure	2302	SNF- Cedar Hebo

Current HSC Activities

An Alder Day in the Woods

On June 16, 2016, the Washington Hardwood Commission (WHC) held a guided tour of red alder plantations in the area of Castle Rock, WA. The tour was held on Weyerhaeuser property and led by (now retired) Weyerhaeuser research forester Alex Dobkowski. The tour covered most aspects of intensively managed red alder plantation activities including site selection, planting stock, soil site index vs. expressed site index, pre-commercial thinning, commercial thinning, etc. The tour handout was a well-made and is available on the WHC website:
http://wahardwoodscomm.com/ppt/16AM/Experience_Alder_Day_in_the_Woods.pdf
The HSC was involved in the organization of this event and gave two presentations. The first, by Glenn Ahrens, gave an overview of the HSC- its objectives, history, organization, members, and current research priorities. The second, by Andrew Bluhm, used the 26-year-old HSC Type 2 installation, Ryderwood, as a backdrop to discuss stand density management as it relates to intensively managed red alder plantations. Topics presented included: a comparison of heights and diameters of the Ryderwood control treatments with the average height and diameters of the thirteen HSC sites used in the subsequent analysis, a description the HSC treatments described, effect of stand density management on relative density, live crown ratio, tree diameter, tree height, stand cubic foot volume at age 22, and projected stand board foot volume at age 35. The following are the key results presented.

- This stop- HSC #3202 is a top performing red alder site across the region. Using the "soil-site method" of estimating site index (Harrington 1986), site index (base age 50 years) was 105ft. Site index estimates of twelve other HSC sites greater than 20 years old ranged from 85ft to 115ft. Ryderwood DBH (Figure 2) and height (Figure 3) for the four control treatments are the maximum, or near maximum observed of the thirteen installations. Therefore, tree and stand growth responses (i.e. Dbh, Ht, Vol, etc.) from this site should be considered "optimal" or "exceptional".

Figure 2- Control treatment, 22 year, all tree DBH for HSC site #3202 (Ryderwood) with the mean (and maximum) of 13 HSC installations.- All Trees

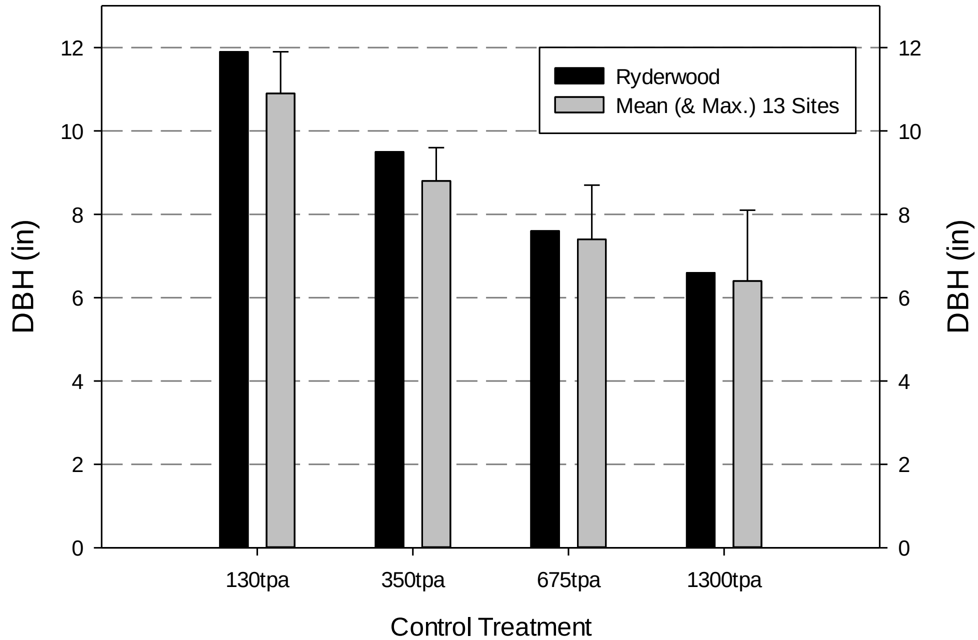
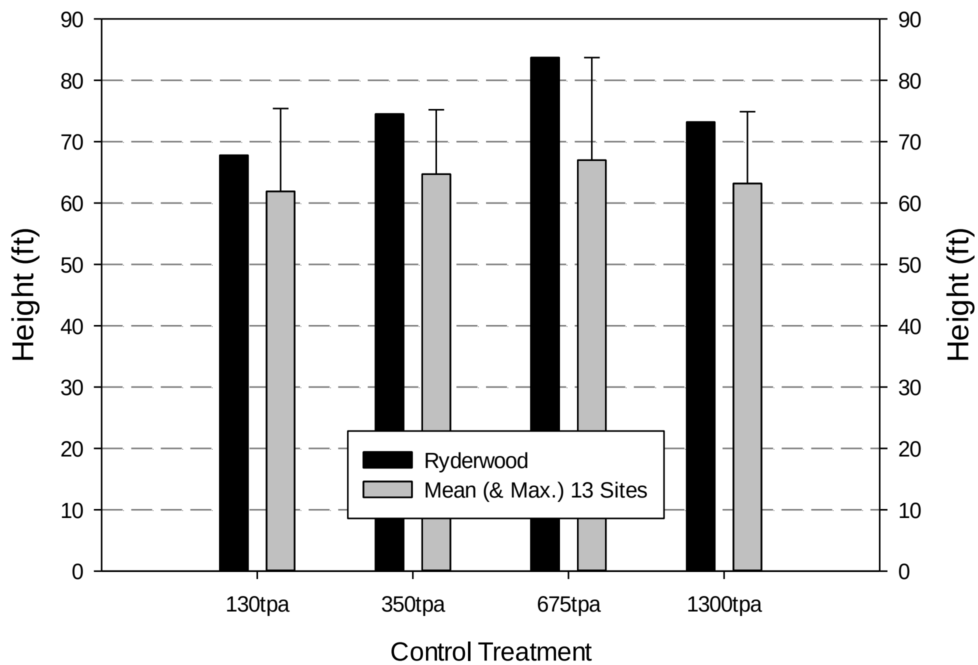
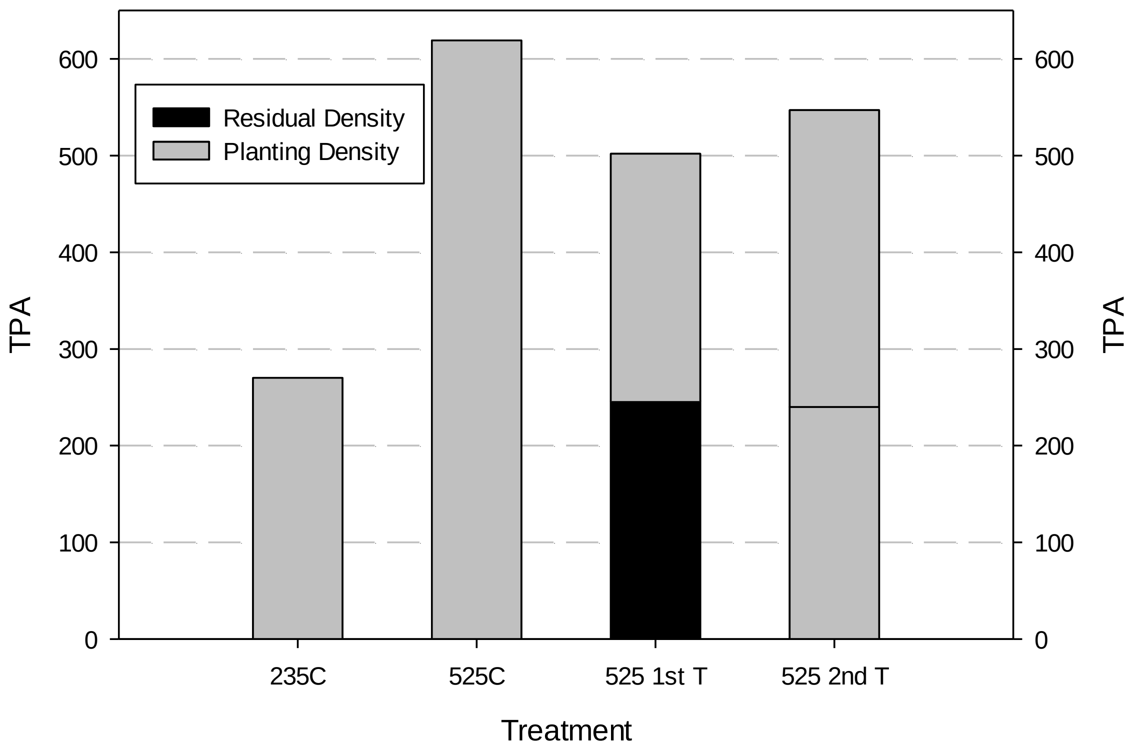


Figure 3- Control treatment, 22 year, all tree height for HSC site #3202 (Ryderwood) with the mean (and maximum) of 13 HSC installations.- All Trees



- The silvicultural treatments presented here (plant at 235tpa & leave alone [235C], plant at 525tpa & leave alone [525C], plant at 525tpa and thin to 240tpa at crown closure [525 1st T], and plant at 525tpa & thin to 240tpa when HLC=15-20ft [525 2nd T]) fall within what is currently considered operational (Figure 4) and furthermore, allow for meaningful comparisons across treatments.

Figure 4- HSC #3202 (Ryderwood): Treatment Densities

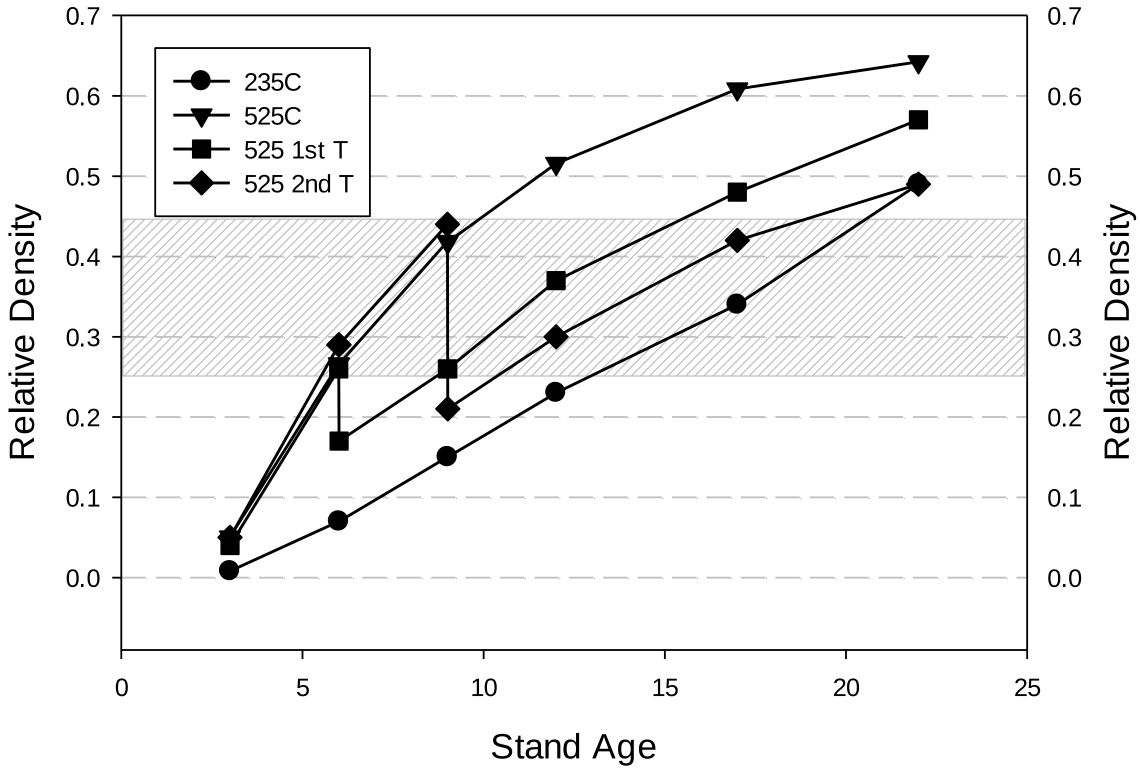


525 1st T=Thin at crown closure: Age=6yrs
525 2nd T=Thin when HLC=15-20ft: Age=9yrs

- Stand density management provides opportunities for foresters to influence stand yield, individual tree size, and stem form. Relative density and the associated relative density diagram is a useful tool in deciding the timing (i.e. "window") and intensity (post-thinning or residual density) of pre-commercial thinning. The recommended management zone (RD=25% to 45%) is the stand condition that is a compromise between individual tree growth, stand yield, and mortality. Using data from this site the following were observed (Figure 5):
  - For the 235C, the recommended management zone (RD=25% to 45%) occurred between the ages of 13 & 20.
  - For the 525C, the plot was in the recommended management zone (RD=25% to 45%) between the ages of 6 &10.
  - For the 525 1st T, thinning occurred at age 6; just as the stand was entering the management zone (RD=26%). It was thinned to a relative density below what is recommended (RD=16%).

- For the 525 2nd T, thinning occurred at age 9; just as the stand was approaching the upper limit of the management zone (RD=44%). It was thinned to a relative density just below what is recommended (RD=21%).
- By age 22, only the 525C treatment has reached the “self-thinning line” (RD=65%).

Figure 5- HSC #3202 (Ryderwood): Relative Density



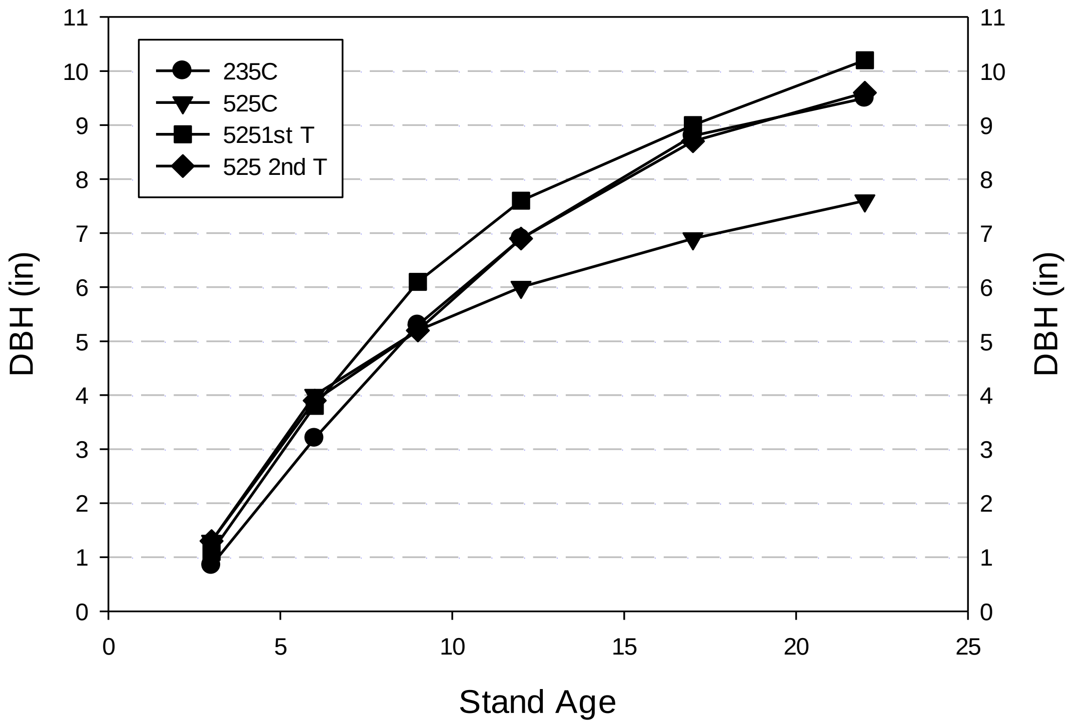
- The increased diameter growth resulting from an increase in resources (i.e. thinning) is, among other factors, a function of crown size. Therefore, identifying crown size is another useful way of deciding when to pre-commercially thin. A simple and useful measure of crown size is live crown ratio (LCR). For red alder plantations, it is generally considered that a 50% LCR of the trees/stand is a desirable “trigger” for when to PCT- thinning when LCR>50% sacrifices stand yield, while thinning when LCR<50% sacrifices individual tree growth. In regards to LCR, the following were observed (data not shown):
  - For the 235C treatment, the trees/stand reached LCR=50% at age 20.
  - The 525C treatment was 12 years old when LCR dropped below 50%.
  - The LCR at time of thinning for the 525 1st T, and 525 2nd T was 84% and 66%, respectively. So, using the 50% rule, these treatments were thinned early.
  - PCTing maintained higher LCRs than the unthinned 525C treatment (~37% vs 27%).

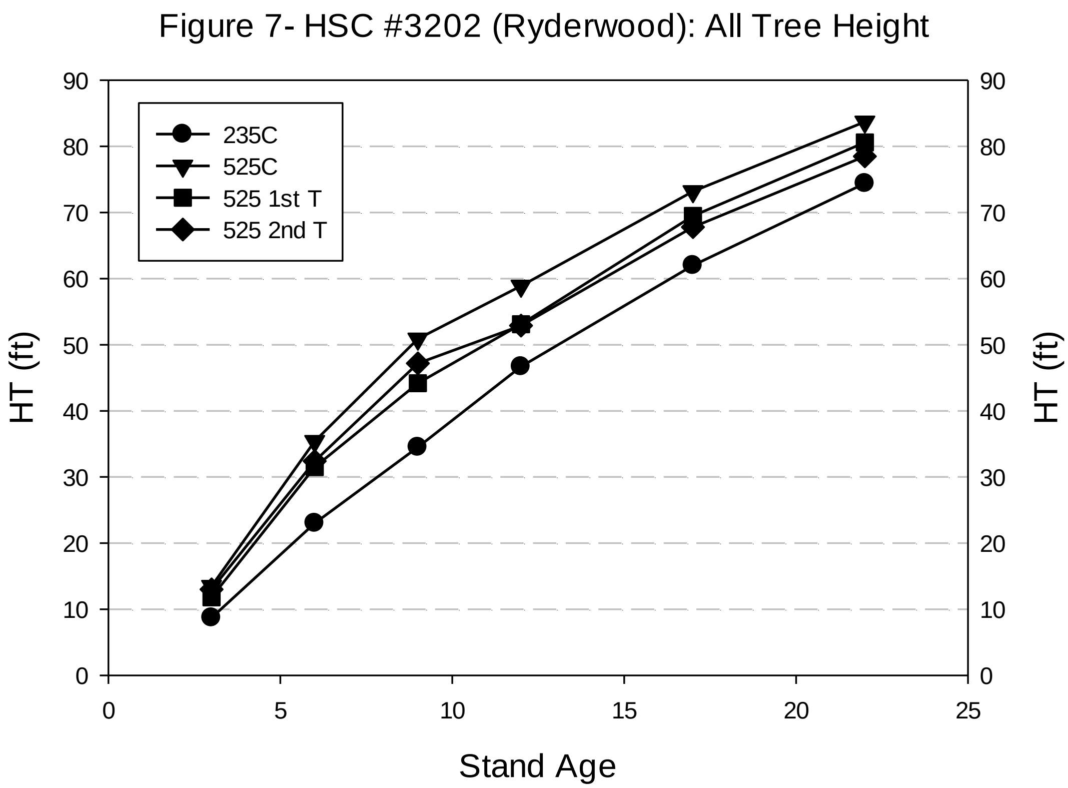
- Diameter (Figure 6):

- Trees either planted at a wider spacing (235C) or thinned to a wider spacing (525 1st T & 525 2nd T) had, on average, diameters 2 to 3 inches (30%) greater than the closer spaced treatment (525C) at age 22.

- Height (Figure 7):
  - Height at age 22 differed by treatment although differences were relatively small. Stands planted at a wider spacing (235C) were shortest (74ft) , followed by thinned stands (~79ft) with closer spaced stands (525C) were tallest (84ft).

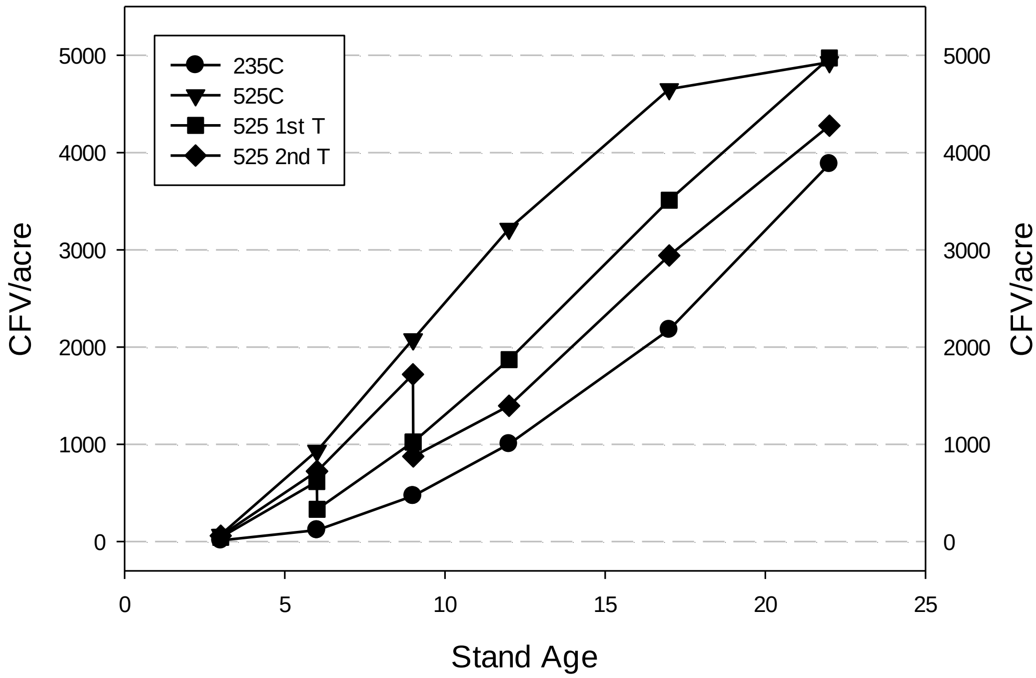
Figure 6- HSC #3202 (Ryderwood): All Tree DBH





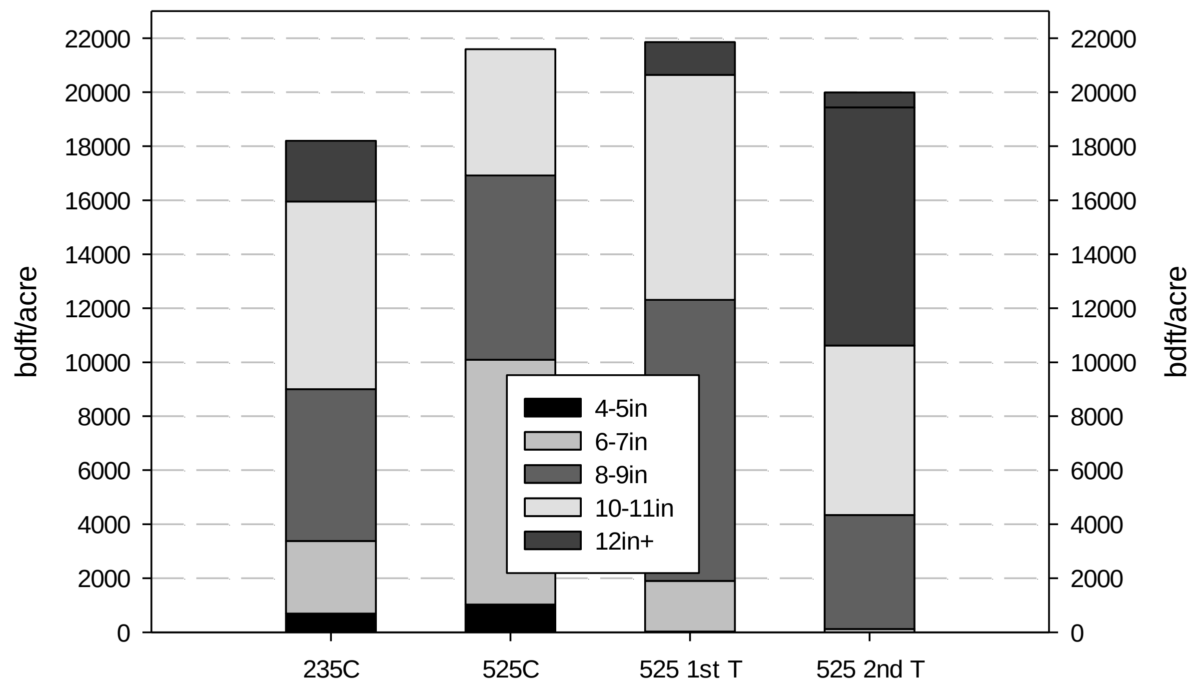
- Total cubic foot volume at 22 years (Figure 8):
    - Through age 20, total stand cubic foot volume per acre (CFV) followed the same patterns as height: stands planted at a wider spacing had the least volume followed by thinned stands followed by closer spaced stands.
    - A severe weather event in 2010/2011 damaged the 525C treatment, resulting in a significant loss of volume.
    - The stand planted at the wider spacing (235C) had the least volume (3900ft^3/acre).
    - Thinning at age 6 (525 1st T) resulted in more volume (5000ft^3/acre) than thinning at age 9 (4300ft^3/acre).

Figure 8- HSC #3202 (Ryderwood): Total Cubic Foot Volume (CFV)



- Board foot volume (BDFV) at 35 years (Figure 9):
  - Using the data collected at age 22 and the red alder growth and yield model (RAP-ORGANON), board foot volume per acre by log diameter class was projected to age 35 (merchandising specifications= log length 32ft, minimum log length 12ft, minimum log diameter 4in, stump height 1ft, and trim 6in).
  - At age 35, BDFV ranged between 18MBF and 22MBF.
  - The greatest volumes were found in the 525C stand (21.6MBF) and the 525 1st T (21.8MBF). Although these two stands had nearly identical total volumes, log diameter distributions varied greatly- the 525C stand had a much higher proportion of smaller logs.
  - The 235C stand had the lowest volume (18.2MBF) as well as the greatest range in log sizes.

Figure 9- HSC #3202 (Ryderwood): Projected Volume; Age 35 by Log Diameter Class



Red Alder Taper Data Collection

As reported previously, the HSC-built taper equation for managed stands of red alder fit the data nicely. However, due to the young age of the plantations, the sampled trees were of pre-merchantable size (Table 7). Consequently, it is important to determine if this taper equation would accurately predict diameter inside bark (dib) and stem volume of larger, merchantable trees. With this in mind, the HSC has been collecting additional taper data opportunistically. This last year, the HSC collected data from sixteen trees from a 45 year-old mixed- species stand from the Siuslaw National Forest as well as data from nine trees from the 22 year-old Type 2 installation Mt. Gauldy (Table 8).

Preliminary evaluations of the taper equation by the HSC revealed mostly consistent under predictions of dib, and thus volume (see HSC 2015 Annual Report) in older (and bigger) managed trees. Another evaluation using additional data from older managed and unmanaged stands indicated the original equation provided the best fit of the data except for in larger trees where the original equation consistently under predicts dib higher up along the stem (see HSC 2016 Annual Report).

Table 7- Red alder taper equation (Bluhm et al. 2007) source data

DBH	Height (ft)																
(in)	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	Total
1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0
2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0
3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0
4	--	--	1	5	4	2	3	3	1	--	--	--	--	--	--	--	--	19
5	--	--	3	5	14	11	11	10	3	3	--	--	--	--	--	--	--	60
6	--	--	1	1	5	7	9	10	4	1	--	--	--	--	--	--	--	38
7	--	--	--	1	4	11	10	7	7	3	3	--	--	--	--	--	--	46
8	--	--	--	--	--	9	11	5	9	2	3	--	--	--	--	--	--	39
9	--	--	--	--	--	2	2	--	10	2	2	--	1	--	--	--	--	19
10	--	--	--	--	--	--	1	3	2	3	1	--	--	--	--	--	--	10
11	--	--	--	--	--	--	--	--	2	1	--	--	--	--	--	--	--	3
12	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0
13	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0
14	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0
15	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0
16	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0
Total	0	0	5	12	27	42	47	38	38	15	9	0	1	0	0	0	0	234

Table 8- Red alder taper equation Winter 2016/17 additional data

DBH	Ht (ft)																
(in)	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	Total
1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0
2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0
3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0
4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0
5	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0
6	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0
7	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	1
8	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0
9	--	--	--	--	--	--	--	--	--	1	1	1	--	--	--	--	--	3
10	--	--	--	--	--	--	--	--	1	1	--	--	--	--	--	--	--	2
11	--	--	--	--	--	--	--	--	1	1	1	--	--	--	1	--	--	4
12	--	--	--	--	--	--	--	--	--	--	1	--	--	--	1	--	--	2
13	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	1	2
14	--	--	--	--	--	--	--	--	--	--	--	--	--	--	3	1	--	4
15	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	2	1	4
16	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	1
17	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	1
18	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	1
Total	0	0	0	0	0	0	0	0	3	3	3	2	0	0	7	4	3	25

Research Results

Effects of species mixtures on growth and yield of red alder and Western redcedar

Abstract

In the Pacific Northwest, monocultures have historically been the predominate form of plantation management. However, the management of mixed-species stands of red alder (*Alnus rubra* Bong.) with associated conifers has recently generated interest. The reasons for this are many: often red alder will regenerate naturally into conifer plantations posing a common management scenario, concerns about improving biological diversity in planted conifer stands, improvement of ecosystem resilience, site productivity enhancements due to red alders**'** nitrogen (N)-fixing ability, and red alder's favorable market value.

The relationships among tree mortality, tree size (DBH, Height, cubic foot volume), and stand yield in planted red alder and western redcedar (*Thuja plicata* Donn. ex D. Don, hereafter referred to as "redcedar") species mixtures were explored at a modified replacement series at a 26 year-old site growing on abandoned agricultural land in northwest Washington, USA. This study is the only one in the USA and the oldest of its kind in existence. Treatments included four species proportions (100% red alder, 25% red alder/75% redcedar, 50% red alder/50% recedar, 100% redcedar) planted at 680tpa (8' x 8' spacing). An additional treatment of pure red alder was planted at 170tpa (16' x 16' spacing) was also included. Redcedar was planted in 1990 and the red alder planting was delayed for seven years (1997 and interplanting in 1998). However, due to early seedling mortality from *Septoria alnifolia*, four of the 13 treatment plots failed and the only pure red alder treatment plot was compromised.

By 2016, redcedar had much higher survival than red alder. The survival of both species was greater in the mixtures than in the pure species treatments. Red alder DBH and height was greatest at the lowest densities of red alder and was independent of the mixed or pure treatments. Redcedar DBH and height were reduced when grown in species mixtures compared to pure species treatments (19% and 10%, respectively). Red alder individual tree cubic foot volume was greatest at the lowest densities and redcedar individual tree volume was greatest in the pure species treatment. Total merchantable stem volume was greatest in the treatments that contained a redcedar component, whether pure or mixed species. Volume in the pure red alder treatments was less than half of that of the treatments that contained redcedar.

In the mixed species treatments, relative yield (RY) of the red alder was >1 (indicating growth enhancement) whereas for redcedar RY was <1 (indicating a growth penalty). Relative land output (RLO) for the mixed species treatments was <1, indicating a substantial increase in per acre productivity as measured by merchantable volume. These positive yield improvements over the pure species treatments were observed mainly as the result of increased survival of both species, increased volume of red alder in the mixed species treatment, and shade tolerance of the redcedar allowing the development of a distinct stratified (two-storied) stand structure. These results demonstrate that there is potential for mixedwood management and that forest managers should consider species mixtures as a means to enhance productivity, yield, and other management objectives.

Introduction

Red alder (*Alnus rubra* Bong.) is a common component of most low-elevation forests in the Pacific Northwest, forming both pure stands and mixed species stands. Usual associates are Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco), Sitka spruce (*Picea sitchensis* [Bong.] Carr), western hemlock (*Tsuga heterophylla* [Raf.] Sarg.), grand fir (*Abies grandis* [Dougl. ex Don] Lindl.), and western redcedar (*Thuja plicata* Don. ex D. Don). The distributions of these species overlap significantly with red alder's distribution. Despite this overlap vast areas of land continue to be managed as conifer monocultures (Cox and Atkins 1979) and in these intensively managed conifer plantations, red alder can threaten full and uniform stocking of the conifer target species (Newton and Cole 1994). Although young red alder is relatively easy to control with some herbicides (Peterson *et al*. 1996), continuing public concern and prohibitions on using herbicides on certain ownerships jeopardizes or limits this use, resulting in a situation where red alder is viewed as a "competitor" in conifer monocultures.

One goal of mixed-species plantation research and management is to determine whether species mixtures can provide greater yields and/or other benefits that may outweigh the advantages of the management simplicity of monocultures. The objective is to mix certain species that will increase stand-level productivity or individual-tree growth rates relative to monocultures, allow the harvest of products from different species on different rotations, potentially reduce the risks of insect or disease impacts, or achieve some combination of these (Forrester *et al*. 2006, Kelty 2006). Furthermore, commitments to improve biological diversity and resiliency (Kelty *et al*. 1992) and the potential for climate change effects (Messier *et al*. 2013) now create interest in management opportunities for more complex multi-species stands. When mixed with even-aged conifer stands in the Pacific Northwest, red alder can increase forest understory plant and wildlife biodiversity and abundance, enhance productivity and biological function of streams (Wipfli *et al*. 2003), and increase conifer growth and total forest growth on certain sites (Binkley 2003). Species mixtures may improve ecosystem resilience by offering some protection from disease and insect outbreaks, resistance to wind damage and other abiotic stresses, and conservation of native plant and animal species (Messier *et al*. 2013).

It is important to identify the effects of species mixtures on growth and stand development. The oft resulting lower timber yields are often considered a necessary sacrifice that accompanies the use of species mixtures unless the component species have good ecological combining ability—that is, the differences in growth characteristics reduce competition or one species has a positive effect on the growth of the other species (Kelty *et al*. 1992). On one hand, as an early- successional, shade-intolerant species, red alder is often an aggressive competitor with young conifer stands; Douglas-fir growth in mixed species stands is often less than in pure stands because of lower light levels. On the other hand, red alders' nutrient cycling characteristics and nitrogen fixing ability can improve the growth of conifers on nutrient poor sites. Tree and stand growth responses vary because the competitive and facilitative effects of red alder differ by associated species and site quality. These processes (competition and facilitation) have been the subject of numerous early investigations (Berntsen 1961, Tarrant and Miller 1963, Newton *et al*. 1968, Trappe *et al*. 1968 (and references within), Miller and Murray 1978, Briggs *et al*. 1978 (and references within), Tarrant *et al*. 1983, Hibbs and DeBell 1994, Miller and Murray 1978, *etc.*). These studies most always investigated red alder and Douglas-fir interactions.

There has been less focus on species mixtures of red alder and other conifer species such as Sitka spruce (Courtin and Brown 2001, Gara *et al*. 1980), western redcedar (Deal *et al*. 2004, Thomas *et al*. 2005), and western hemlock. Of special note, these mentioned species are all more shade tolerant than Douglas-fir (Minore 1979). Ecological theory suggests that species having very different growth characteristics such as height, form, photosynthetic efficiency of foliage, and root structure may have a good ecological combining ability, which allows them to coexist in mixtures with high productivity (Harper 1977, Kelty *et al*. 1992). The relationship between juvenile growth rates and shade tolerance plays an important role in mixed species plantations (Menalled *et al*. 1998). In general, intolerant species grow rapidly in height and have crowns with low leaf area density. These species can form an upper canopy stratum that transmits some light to shade tolerant species that form a lower stratum (Kelty 2006). Canopy stratification of this kind is an important aspect of complementary resource use.

Because of the promising ecological combining ability of redcedar with red alder and because of both species high-value wood products, redcedar could be grown with red alder as a mixed species plantation and harvested in two stages (Stubblefield and Oliver 1978). Understanding relationships between these species may enable silviculturists to design specific mixtures that provide ecosystem resilience while maintaining or surpassing timber yields or other ecosystem goods and services at greater levels than monocultures (de Montigny and Nigh 2007). For instance, the red alder component could be removed when it reaches commercial size and the redcedar left growing as a second crop. The advantage of this system is that the understory redcedar would reduce the size and number of limbs, sweep and lean of the red alder (Grotta *et al*. 2004), thus improving wood quality. In addition, the growth of the redcedar might be improved due to the added nitrogen fixed by the red alder (Shainsky and Radosevich 1992, Binkley 2003). The disadvantages of this system is that there is likely some reduction in growth of either or both species, and the increased management and harvesting difficulties and cost.

Decisions about planting mixtures require an understanding of the survival and growth rates of the different species when grown together at different proportions and densities (de Montigny and Nigh 2007). To better understand both the competitive and facilitative effects of a red alder and redcedar species mixture, a modified replacement series experiment was established near Mt. Vernon, WA. The redcedar was planted in 1990 and the red alder planted in 1997 and 1998. In this replacement series, total stand density remained constant (680tpa) with four species proportions (100% red alder, 25% red alder/75% redcedar, 50% red alder/50% recedar, 100% redcedar). The site was measured in 2003 (when the redcedar was 13 years old and the red alder 6 years old) and again in 2016 (when the redcedar was 26 years old and the red alder 19 years old). The objective of this research is to examine the effects of species proportion on 1) survival, 2) diameter at breast height (DBH), 3) height (HT), 4) individual tree volume, 5) volume per acre, and 6) relative yields of both the red alder and the redcedar.

Material and methods

Site Characteristics

This long-term experiment was established on Pacific Denkmann Co. property south of Mt. Vernon, WA. The site is located at longitude and latitude of 48.316^0, -122.280^0 (T33N R4E Sec 27) within four miles of the Puget Sound at 350ft elevation. Average minimum and maximum temperatures are 42^0 F and 59^0 F, respectively. Average annual precipitation is 65in, which occurs primarily between October and May (growing season precipitation 10.7in). The growing season has relatively mild temperatures and a high percentage of cloudy days even during summer. The soil is Norma silt loam; a poorly drained gravelly sandy loam overlain with ashy silt loam. Previous vegetation was pasture/old field. According to the Natural Resources Conservation Service (NRCS) 'Web soil survey' this soil type is "prime farmland if drained". Douglas-fir site index is unknown. Red alder site index of 50 years (Worthington *et al*. 1960) is given to be 90ft (NRCS). Using the red alder soil/site evaluation method of Harrington (1986), site index was estimated at 69ft (converted to base age 20 years as in Thrower and Nussbaum 1991). Using the measured 26 year-old dominant tree heights (H40) site index (base age 20 years) was calculated as 86ft for 100% 16'RA and 73ft for the 100% 8'RA treatments (Weiskittel *et al*. 2009).

Site preparation consisted of digging drainage ditches in the spring of 1988, sprayed with glyphosate in the summer of 1988 and then rototilled in the early fall of that year. In 1989, the site was sprayed with glyphosate in early summer and then rototilled again in the fall.
Redcedar seed was gathered from second growth stands in previous years. The plug-1 cedar were grown at an unknown nursery and planted in February to March of 1990. They were hand sprayed with glyphosate around the base several times during the summers between 1990 and 1998. Red alder seed was gathered from an adjacent stand in the fall of 1995. The 1-0 red alder seedlings grown by Weyerhaeuser Company were planted in March of 1997. Heavy mortality occurred the first year from *Septoria alnifolia*. More red alder seedlings were interplanted in the winter of 1998. Between the two successive plantings, satisfactory survival was attained in most of the mixed species plots but in few of the pure red alder plots. Looking at historical photos, four of the fifteen plots failed just after stand establishment and an additional two were excluded prior to the 2016 measurements.

Some red alder ingrowth is currently present but not as much as the author would expect (personal observation) indicating the removal of any red alder ingrowth in the past. In 2012 the redcedar was pruned to approximately 6ft. Due to the presence of multiple stems the red alder does not appear to have been form pruned.

Experimental Design

In a replacement series experiment (Jolliffe *et al*. 1984), two species are planted together in a succession of different proportions, while keeping the total number of trees per acre constant. In this experiment red alder and redcedar were planted in a series of four proportions (Table 1). Each treatment was planted to an initial target density of 680 trees per acre (8ft by 8ft spacing), in a plot consisting of a sixteen by sixteen tree grid (0.38 acre), surrounded by a single tree buffer (8ft) on all sides. In addition to these replacement series treatments, there is an additional treatment where red alder is planted to an initial target density of 170 trees per acre (16ft by 16ft spacing), consisting of a twelve by twelve tree grid (0.85 acre) and a single tree buffer (Figure 1). This wider spacing resulted in the same density of red alder as the 25% red alder/75% redcedar treatment.

The desired pattern and density was strictly controlled, the trees are in exact rows, columns, and proportions. Three replications of each treatment were established, for a total of fifteen plots (5 treatments x 3 replications), however severe mortality resulted in six plots to be dropped from the study.

Table 1. Treatment description [1] used in the Pilchuck replacement series experiment.

Treatment	Proportion of red alder	Proportion of redcedar	Trees/acre	Spacing (ft)
A- 100%RC	0.00	1.00	680	8
B- 25%RA/75%RC	0.25	0.75	680	8
C- 50%RA/50%RC	0.50	0.50	680	8
D- 8'RA	1.00	0.00	680	8
E- 16'RA	1.00	0.00	170	16

[1]The letters correspond to the treatment letters in Figure 1.

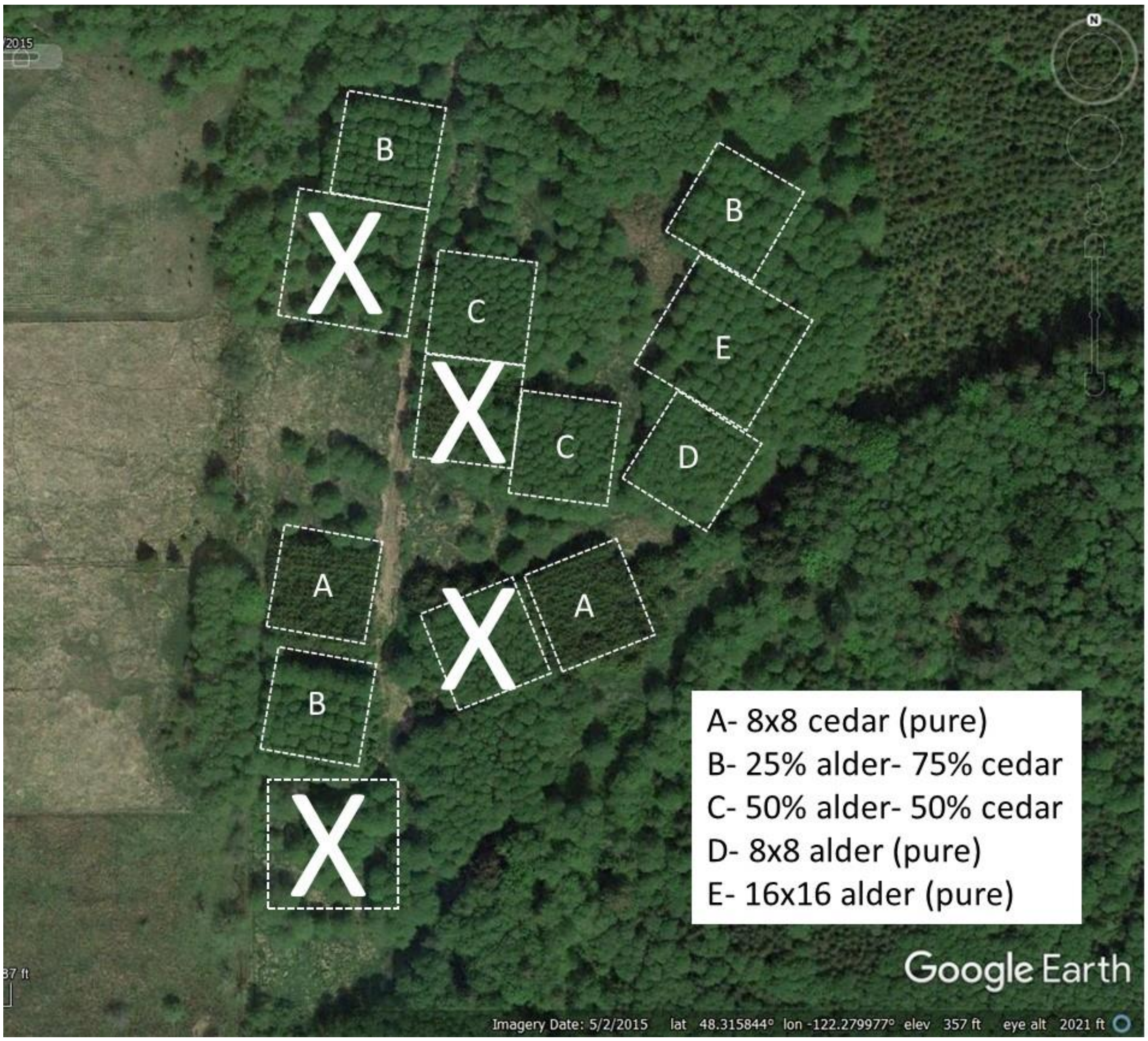


Figure 1- Pilchuck Tree Farm red alder/redcedar replacement series experiment.

Measurements

In December 2003, the site was monumented, trees were tagged, and DBH (stem diameter at 4.5ft) was measured on all trees (Jeffery DeBell, WA DNR, personal communication). Height and height to live crown was not measured. Then in December 2016, the site was remeasured by the Hardwood Silviculture Cooperative (HSC). For every tree, DBH, stem defect (fork, lean, sweep) and presence or absence of damage was recorded. Height (HT) was systematically measured on a subsample of approximately 35 trees/species/plot. Thus, the number of height samples varied by treatment and mortality (Table 2). Height to live crown (HLC) was measured for the 100% red alder treatments only. As previously mentioned, all redcedar had been pruned to approximately 6ft with no crown lift occurring, and the HLC of red alder in the mixed plots corresponded with the height of the redcedar (personal observation).

C		A	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A
A	116	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C
C	115	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A
A	114	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C
C	113	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A
A	112	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C
C	111	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A
A	110	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C
C	109	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A
A	108	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C
C	107	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A
A	106	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C
C	105	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A
A	104	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C
C	103	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A
A	102	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C
C	101	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A
		501	502	503	504	505	506	507	508	509	510	511	512	513	514	515	516	
A		C	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C

Figure 2- Example (Treatment C- 50%RA/50%RC) of plot layout for the Pilchuck Tree Farm red alder/redcedar replacement series experiment. A=red alder. C=redcedar. Trees inside the bold square were used in this analysis.

To increase the buffer and minimize edge effects, all trees in the outer perimeter of the measurement plots were excluded from analysis (see the bold line in Figure 2) resulting in 196 and 100 sample trees per plot for treatments A-D and for treatment E, respectively. Red alder, missing 2016 HTs and crown ratios were estimated using the RAP-ORGANON growth model. The model was then used to calculate individual tree (INDVOL) and per acre volume [(PAVOL) ft^3 and ft^3/acre, respectively]. For redcedar, missing 2016 HTs were estimated by using the parameters obtained by linear regression of HT vs. DBH of the sample trees (data not shown). Individual tree, merchantable volume (6in stump & 4in top [INDVOL]) and per acre volume (PAVOL [ft^3 and ft^3/acre, respectively]) for redcedar was calculated using the taper equation from Kozak (1988).

Statistical Analysis

The total number of trees used in the analysis was 523 red alder and 990 redcedar. Survival was calculated as the number of living trees present (in 2003 and 2016) divided by the expected number of trees for the given treatment. Ingrowth and forks below DBH were excluded from survival calculations. DBH (2003 and 2016) was calculated as the treatment quadratic mean diameter. HT, HLC, Height/Diameter ratio (HD) and INDVOL (2016 only) was calculated as the treatment arithmetic mean. PAVOL was calculated by summing INDVOL for each species/treatment combination multiplied by the plot expansion factor. Analysis was done on each species separately and for PAVOL on both species combined.

PAVOL (2016) was then used to calculate relative yield (RY); defined as species mixture yields relative to yields in pure species treatments (Harper 1977). Effects on RY were examined using two methods. Total relative yield (RYT) = (the yield of Douglas-fir in mixture + the yield of red alder in the mixture)/ (the yield of Douglas-fir in pure stand + the yield of red alder in pure stand) and relative land output (RLO) = (the yield of Douglas-fir in mixture + the yield of red alder in the mixture)/ (the equivalent fraction of Douglas-fir in pure stand + the equivalent fraction of red alder in pure stand). Relative yield total (RYT) was obtained as the sum of RY of both species.

Treatment differences by species were tested using the GLM (general linear model) procedure in SAS. Pairwise comparisons between the treatments were tested using least significant differences and to control the overall type 1 error rate. Pairwise comparisons compare the responses across all treatment levels to determine which responses are statistically different.

Results and Discussion

Survival

Survival by treatment ranged from 59% to 94% in 2003 and between 51% and 90% in 2016 (Figure 3). For both measurement years, survival in the 8’RA treatment was significantly lower than all other treatments. In 2003 survival in the 16’RA treatment was significantly lower than the treatments containing redcedar. In 2016, the 16’RA survival was significantly lower than the 25%RA/75%RC. In both 2003 and 2016 survival in the treatments with redcedar (8’RC, 25%RA/75%RC and 50%RA/50%RC) were greater than survival in the pure red alder treatments; but not significantly different from each other.

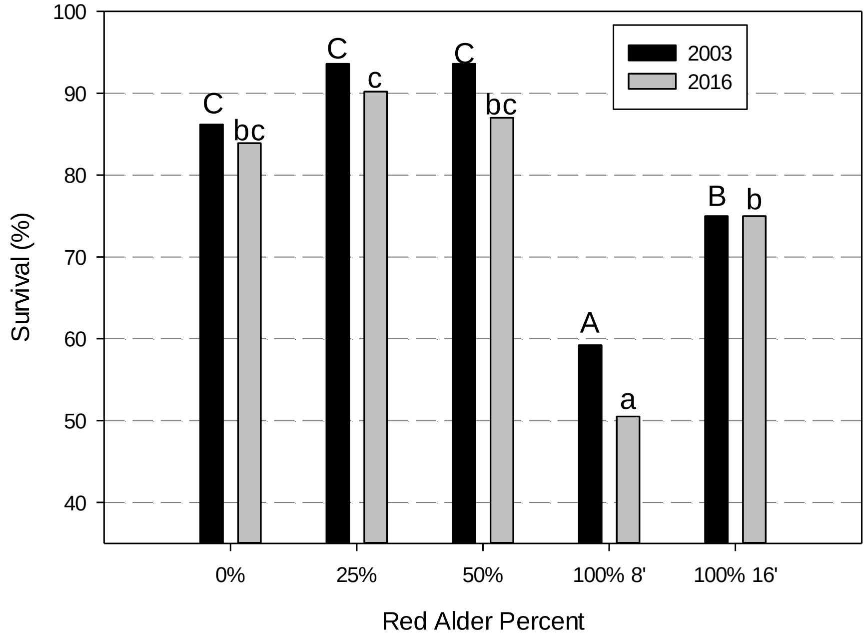


Figure 3- Survival by treatment and year for the Pilchuck Tree Farm red alder/redcedar replacement series experiment. Different upper- and lower-case letters indicate significant differences among treatments for red alder and redcedar, respectively.

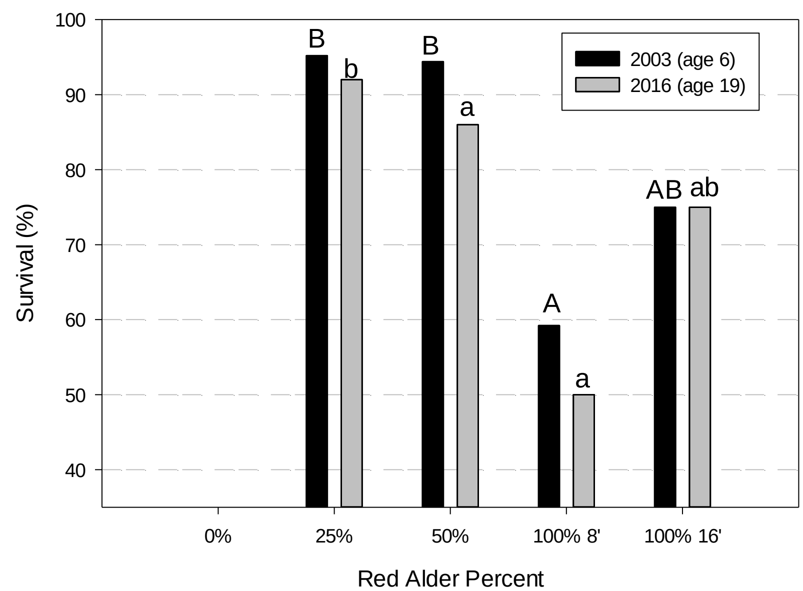


Figure 4- Red alder survival by treatment and year for the Pilchuck Tree Farm red alder/redcedar replacement series experiment. Different upper- and lower-case letters indicate significant differences among treatments for red alder and redcedar, respectively.

Red alder survival by year and treatment is shown in Figure 4. In both measurement years, survival was lowest in the 8'RA, then the 16'RA, followed by the mixed species treatments. However, this significant reduction in survival is likely not an effect of density. First, by age 6, survival was below 60%- much lower than the self-thinning line would suggest (Puettman *et al*. 1993). Second, mortality appears to be a combination of sunscald/heat stress (since most mortality is confined to the unprotected, south edge of the plot) and the canker, *Neonectria major* (Figure 5). Third, the crown ratio of trees in this plot, although significantly lower than the other treatments, was 39% (data not shown) - indicating a still vigorous crown condition before the onset of density dependent, intraspecific mortality. Fourth, relative density was 0.40 (data not shown) – far below the self-thinning line. This plot would normally not be used in this analysis, however, this treatment is not replicated. This analomy /irregularity severely limits the usefulness of this plot for further comparisons of treatment effects (DBH, HT, VOL, etc.).

Figure 5- Example of *Neonectria major* found in the 8'RA treatment at the Pilchuck Tree Farm red alder/redcedar replacement series experiment.

The best red alder survival was found in the mixed species treatments with approximately 95% and 89% survival for the 25%RA/75%RC and 50%RA/50%RC, respectively for both measurement years. Although the red alder component is identical for the 25%RA/75%RC and the 16’RA, survival was greater (but not significantly) for the red alder grown with the cedar (93%) compared with the pure treatment (75%). This result- a positive effect on red alder survival by redcedar- was unexpected. The increased survival may be attributed to the shading/cooling effect the cedar may have had on the young red alder.

Redcedar survival was very high across treatment and measurement year despite no browse protection (Figure 6). In 2003, the 8’RC treatment had lower survival (86%) than the mixed species treatments, being significantly lower than the 50%RA/50%RC treatment (93%). In 2016, this pattern remained the same where the 8’RC survival (84%) was significantly lower than the 50%RA/50%RC treatment (87%). So, like red alder, redcedar survival was greater in the mixed species treatments. This result is in contrast to the results found in de Montigny and Nigh (2007) where there was no effect on redcedar survival after 14 years when grown as a pure species or grown with varying proportions of Douglas-fir.

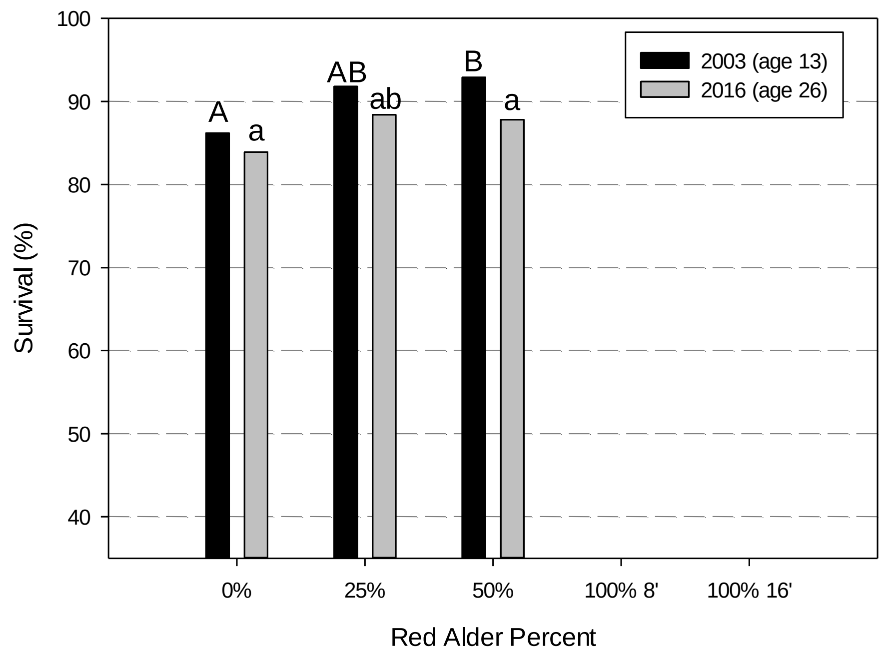


Figure 6- Redcedar survival by treatment and year for the Pilchuck Tree Farm red alder/redcedar replacement series experiment. Different upper- and lower-case letters indicate significant differences among treatments for red alder and redcedar, respectively.

Diameter (DBH)

In 2003, plot level quadratic mean diameter (DBH) ranged from 4.4in to 6.8in with the greatest DBH in the pure redcedar treatment and declining with increasing red alder proportion (data not shown). The likely reason being that the redcedar was more than twice as old as the red alder (13 years and 6 years, respectively). By 2016, DBH ranged from 7.5in to 10.8in with the greatest DBH now occurring in the 16'RA treatment. For both measurements the 100% 8'RA had the smallest DBH of all treatments as discussed above (data not shown).

Red alder quadratic mean diameter (DBH) by year and treatment is presented in Figure 7. For both the 2003 and the 2016 measurements, red alder DBH was greatest for the treatments with the lowest densities of red alder- regardless whether in pure (16'RA) or mixed (25%RA/75%RC) species treatments. This might indicate that red alder DBH is more sensitive to intraspecific competition than interspecific competition with the redcedar. These results are consistent with the Thomas *et al*. (2005) replacement series (red alder/Douglas-fir), where 12 year old red alder DBH was greater in the mixed species treatment (150tpa red alder/150tpa Douglas-fir) than in the pure red alder treatment. It is also consistent with the findings of Radosevich *et al*. (2006) where red alder DBH was greater in mixed species treatments with Douglas-fir as compared to the pure red alder treatments on both high- and low-quality sites.

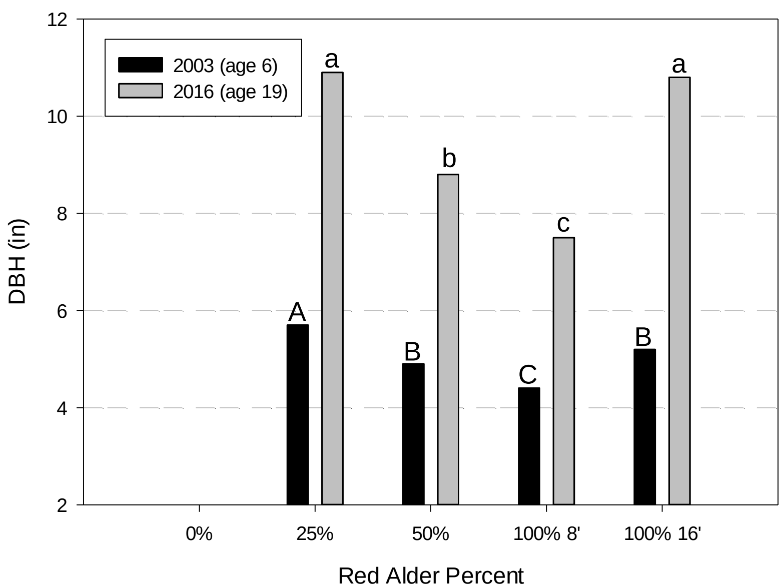


Figure 7- Red alder DBH by treatment and year for the Pilchuck Tree Farm red alder/redcedar replacement series experiment. Different upper- and lower-case letters indicate significant differences among treatments for red alder and redcedar, respectively.

As shown in Figure 8, DBH of redcedar in 2003 was significantly greater in the 25%RA/75%RC treatment (7.2in) than the other two cedar treatments (6.8in for the 100% 8'RC and 6.9in for the 50%RA/50%RC). Practically, this difference was 5.7% and 4.2% respectively. This result is consistent with de Montigny and Nigh (2007) who found that, although not significant, redcedar DBH at age 14 was slightly greater when mixed at a 1:3 ratio as compared to a 1:1 ratio with Douglas-fir. However, in 2016, redcedar DBH was significantly greater in the pure treatment (8'RC), averaging 10.0in than in either of the mixed species treatments (8.4in for both the 25%RA/75%RC and 50%RA/50%RC). This result indicates that there is a "penalty" of a 19% reduction of redcedar DBH when grown in any proportion with red alder. This reduction in redcedar DBH in mixed species treatments is in contrast to the findings of Thomas *et al.* (2005) in their additive series experiments (redcedar/Douglas-fir and added red alder) where redcedar DBH at age 12 was greatest when red alder was present in either 40tpa or 80tpa densities.

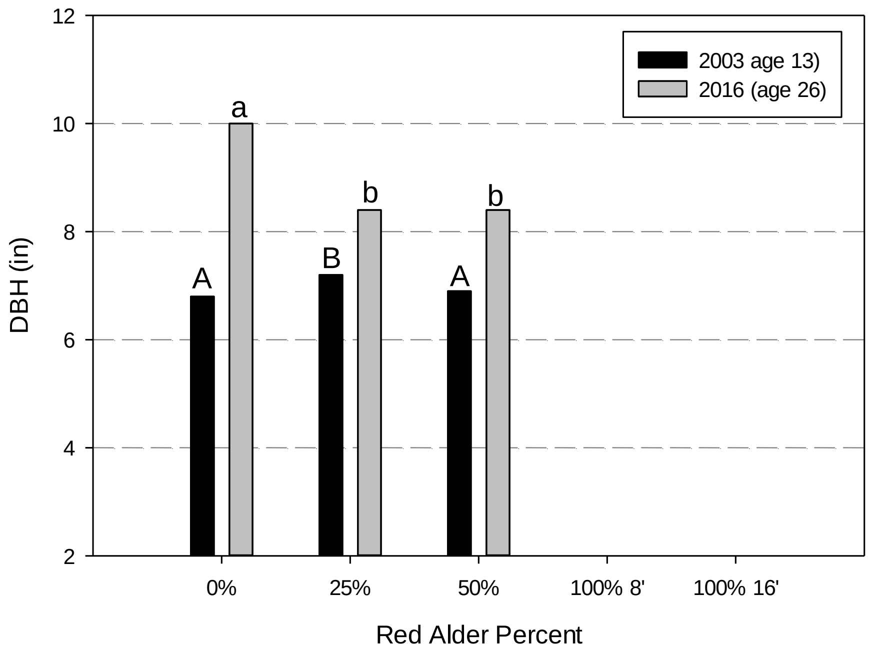


Figure 8- Redcedar DBH by treatment and year for the Pilchuck Tree Farm red alder/redcedar replacement series experiment. Different upper- and lower-case letters indicate significant differences among treatments for red alder and redcedar, respectively.

Tree height (HT)

Red alder clearly overtopped the redcedar (Figure 9). After 26 years, the redcedar averaged 42.0ft while after 19 years, the red alder was 73.1ft (1.7 times greater). HT differed significantly by treatment, ranging from 44.7ft for the 100% 8'RC to 76.3ft for the 100% 16'RA treatment. HT increased as the proportion of red alder in the plot increased (data not shown).

Figure 9- A 2016 example of the 25% red alder/75% redcedar treatment clearly showing the height stratification by species for the Pilchuck Tree Farm red alder/redcedar replacement series experiment.

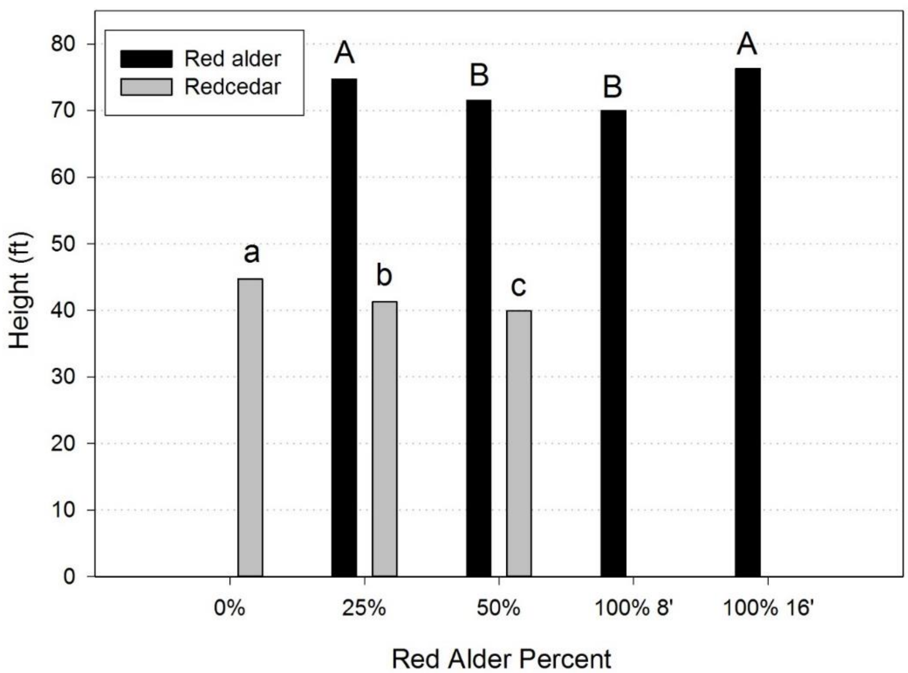


Figure 10- Height by species and treatment for the Pilchuck Tree Farm red alder/redcedar replacement series experiment. Different upper- and lower-case letters indicate significant differences among treatments for red alder and redcedar, respectively.

HT by species and treatment is presented in Figure 10. For red alder, HT ranged from 70.0ft to 76.3ft. Like DBH, red alder HT was greatest for the treatments with the lowest densities of red alder-regardless whether of pure (16'RA) or mixed (25%RA/75%RC) species. This finding that the HT of red alder planted seven years after the redcedar had the same height as the pure red alder treatment is in contrast to the findings of Radosevich *et al*. (2006) where red alder height was 40% less when planting was delayed five years after Douglas-fir on both high- and low-quality sites. However, unlike DBH, red alder HT is either insensitive to density or positively correlated with density (Bluhm, unpublished) up until about this age. It is the author's hypothesis that the 8'RA treatment would have the greatest height if it did not suffer the severe damage and that red alder HT would decrease with decreasing proportion of red alder. This relative insensitivity in red alder HT to mixed or pure species treatment is consistent with the findings of Thomas *et al*. (2005) in their replacement series experiment.

Redcedar HT was significantly greater in the pure treatment (100% 8'RC), averaging 44.7ft, than in either of the mixed species treatments (41.3ft and 39.9ft for the 25%RA/75%RC and 50%RA/50%RC, respectively). This pattern is similar to that of DBH where HT is greatest in pure stands as compared to species mixtures. There is a redcedar height growth "penalty" of about 10% when grown with red alder in species mixtures. Like DBH, this reduction in redcedar HT is in contrast to the findings of Thomas *et al*. (2005) in their additive series experiments where they found the height of redcedar at age 12 was greatest when red alder was present in either 40tpa or 80tpa densities and in contrast with de Montigny and Nigh (2007) who found that redcedar HT at age 14 was not affected whether growing in pure or mixed species treatments with Douglas-fir. At least statistically, however, redcedar height continued to decrease with increased red alder proportion. This indicates that redcedar height growth may be more sensitive than DBH growth when grown with various proportions of red alder. Practically, however, redcedar height varied by less than 5ft.

Height/Diameter (H/D)

H/D by species and treatment is presented in Figure 11. For red alder, H/D increased with increasing density. This relationship is consistent with the theory that diameter is more sensitive to competition (intra- and inter-) than height. Given the site productivity and planting densities, the red alder is experiencing increased intra-specific competition as the treatments approach the self-thinning line. There were no significant differences in H/D at the lowest densities of red alder (16'RA and 25%RA/75%RC), indicating that the presence of redcedar had no effect or red alder stem shape. H/D of redcedar across treatments was considerably lower than reported in the literature (e.g. Wang and Hann 1988, Hanus *et al*. 1999). Redcedar H/D was significantly greater in the pure treatment (8'RC), averaging 59.0, than in either of the mixed species treatments (63.1 and 59.9 for the 25%RA/75%RC and 50%RA/50%RC, respectively). This pattern in H/D is likely driven by the similar pattern observed for that of DBH.

As for most plants, changes in allometry were expected in red alder and redcedar in response to intra- or interspecific density stress (Knowe and Hibbs 1996, Shainsky and Radosevich 1992). This response in plant allometry for red alder is most often associated with intra-specific competition and for redcedar reduced radiation caused by shading of an overstory canopy (Smith 1962).

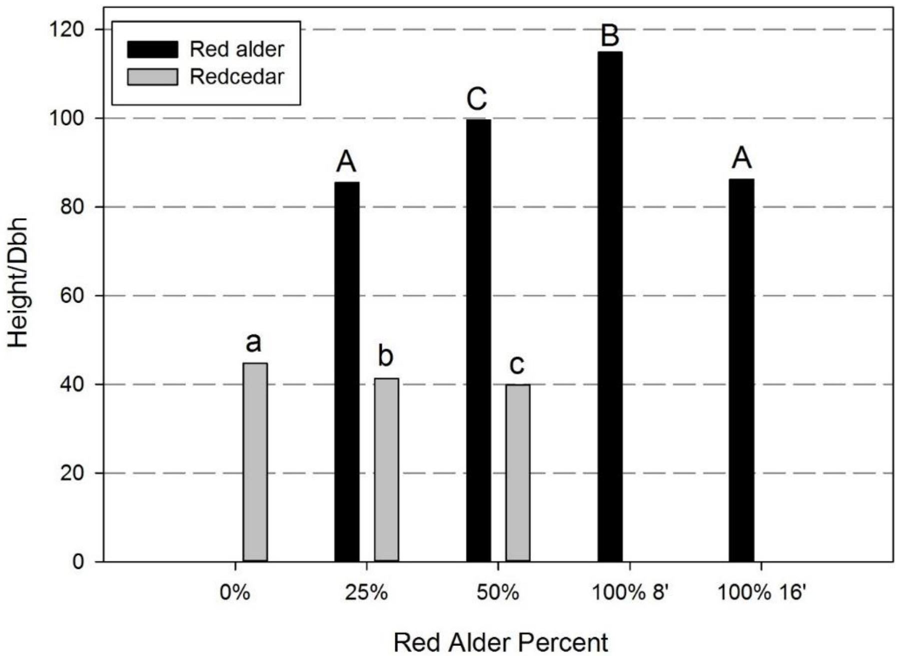


Figure 11- Height/DBH by species and treatment for the Pilchuck Tree Farm red alder/redcedar replacement series experiment. Different upper- and lower-case letters indicate significant differences among treatments for red alder and redcedar, respectively.

Individual Tree Volume (INDVOL)

INDVOL by species and treatment is presented in Figure 12 (INDVOL averaged across species not presented). For both species, INDVOL followed the same pattern and statistical significance as DBH. For red alder, INDVOL was greatest for the treatments with the lowest densities of red alder- regardless whether of pure (18.9 ft^3 for the 16'RA) or mixed (19.2 ft^3 for the 25%RA/75%RC) species treatments. The 50%RA/50%RC treatment had the next highest INDVOL (11.5ft^3) while the RA 8' treatment has the lowest INDVOL (7.5ft^3). However, like DBH, the pattern for INDVOL would be different if the 8'RA treatment did not suffer severe damage.

Redcedar INDVOL was significantly greater in the pure treatment (8'RC), averaging 10.4ft^3, than in either of the mixed species treatments (6.8ft^3 and 6.4ft^3 for the 25%RA/75%RC and 50%RA/50%RC, respectively). So, like DBH and HT, there is a "penalty" of about 35% to 38% for redcedar INDVOL when grown with red alder in these species mixtures. This result of reduced individual tree volume at red alder densities of 170tpa and 340tpa is somewhat consistent with the same additive study of Thomas *et al*. (2005), reported by Comeau *et al*. (2004) that red alder had little effect on individual tree volume growth of redcedar when red alder densities are below 160tpa. Yet these results are in contrast with de Montigny and Nigh (2007) who found that redcedar individual tree volume at age 14 was not affected whether growing in pure or mixed species treatments with Douglas-fir.

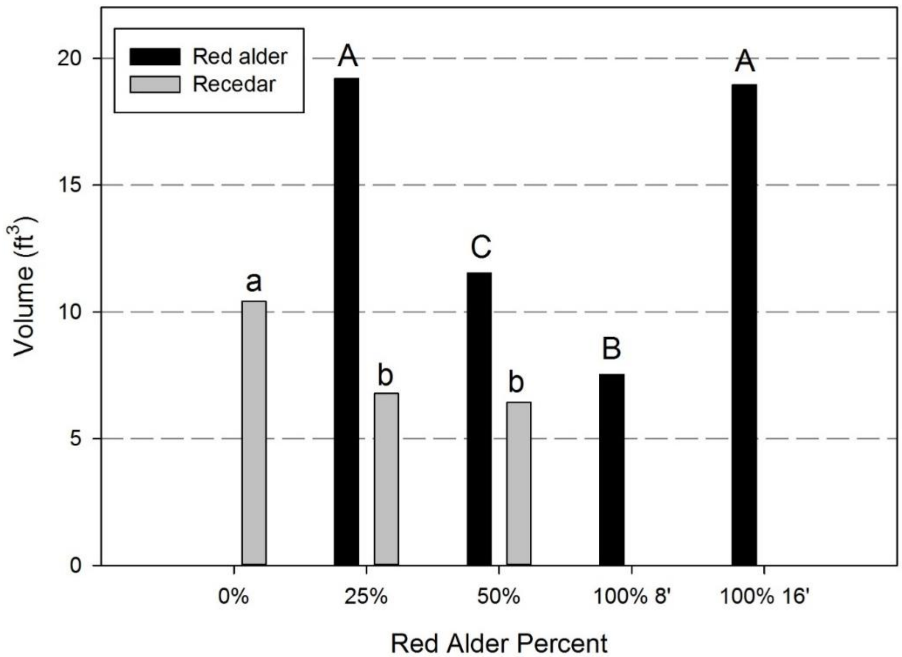


Figure 12- Mean individual tree volume (INDVOL) by species and treatment for the Pilchuck Tree Farm red alder/redcedar replacement series experiment. Different upper- and lower-case letters indicate significant differences among treatments for red alder and redcedar, respectively.

Per Acre Tree Volume (PAVOL)

Total PAVOL by treatment is shown in Figure 13. The pure red alder treatments had approximately half the stand yield as the mixed species treatments. This is not an unexpected result. Because these treatments are essentially stratified with the red alder in the overstory and the redcedar in the understory, the pure red alder treatments lacked the second component of stand volume. Further comparisons of the pure species treatments, shows that the pure redcedar treatment had a striking 2.4 and 2.3 times more volume than the 16' RA and the 8' RA treatments, respectively. The pure redcedar treatment contained a high density of large trees. Even if the 8'RA treatment did not suffer damage, the pure redcedar treatment would still have significantly more volume (pers. obs.). The mixed species treatments had slightly more PAVOL (6053ft^3/acre for the 25%RA/75%RC) or somewhat less (5303ft^3/acre for the 25%RA/75%RC) than the pure redcedar treatment. However, these differences were not statistically significant (data not shown).

Species PAVOL by treatment is also presented in Figure 13. For red alder, the pure treatments (8'RA and 16' RA) had about 2500 ft^3/acre- about half of the volume found in the other treatments (but, once again, if the 8'RA treatment did not suffer severe damage, the PAVOL would be closer to 5000ft^3/acre). In the lowest densities of red alder (170tpa) there were no statistically significant differences between the pure (2417ft^3/acre for 100% 16'RA) or the mixed (2999ft^3/acre for 25%RA/75%RC) treatments. Practically, however, the yield in the mixed species treatment was not only 24% greater than the pure treatment, the stem (log) quality was greatly improved due to the shading of the lower bole by the redcedar (Figure 14).

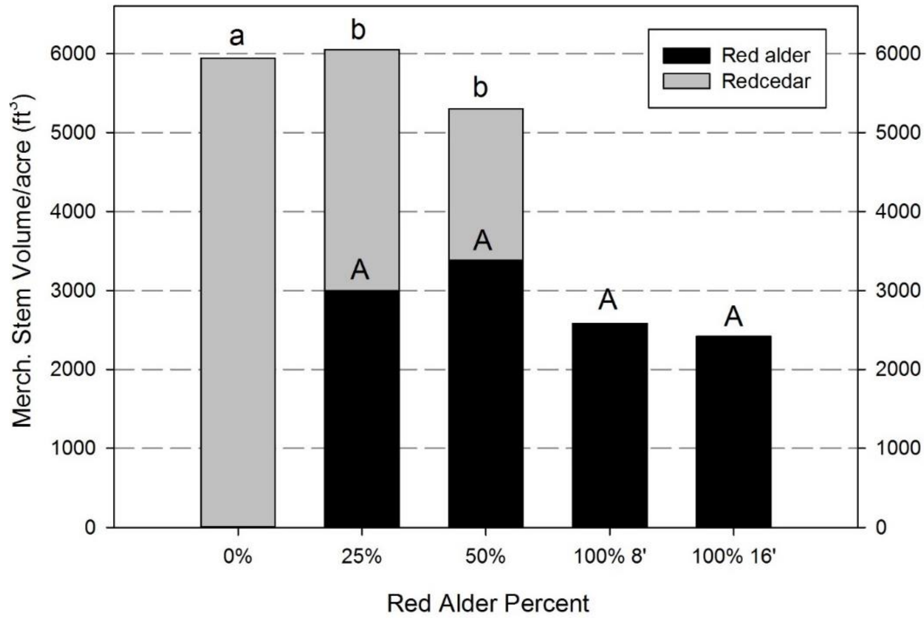


Figure 13- Merchantable volume per acre (PAVOL) by species and treatment for the Pilchuck Tree Farm red alder/redcedar replacement series experiment. Different upper- and lower-case letters indicate significant differences among treatments for red alder and redcedar, respectively.

Figure 14- Examples of differences in stem form between the 25% red alder/75% redcedar treatment and the 16' pure red alder treatment. In both cases, the red alder is planted to 170 trees per acre.

Not surprisingly, redcedar PAVOL was significantly greater in the pure treatment (8'RC), averaging 5942ft^3/acre. In the mixed species treatments, redcedar PAVOL was 3054ft^3/acre and 1918ft^3/acre for the 25%RA/75%RC and 50%RA/50%RC, respectively. Yet these differences between these two yields were not significantly different due to the limited number of replications and the high variability.

Relative Yield

Relative yield is an indicator of the production enhancement (>1) or penalty (<1) when species are planted in mixtures (Jolliffe 1997). Three measures of relative yield are used here:

1) Relative Yield (RY) is the yield of a given species in mixture/ the equivalent fraction of said species in pure stand.
2) Relative yield total (RYT) compares the yields of both species when planted separately. RYT = (the yield of red alder in mixture + the yield of redcedar in the mixture)/ (the yield of red alder in pure stand + the yield of redcedar in pure stand).
3) Relative Land Output (RLO) is the sum of the individual species RYs. RLO = (the yield of red alder in mixture + the yield of redcedar in the mixture)/ (the equivalent fraction of red alder in pure stand + the equivalent fraction of redcedar in pure stand).

The very low PAVOL for the severely damaged pure red alder treatment (RA 8') significantly affected the relative yield comparisons (except for RY of redcedar). Red alder RY and the mixed species treatment RYT and RLO values were much >1 (data not shown). Usually these results indicate heightened production of these species mixtures compared to pure stands of either species. However, in this case, these results were much greater than reported elsewhere (Binkley *et al*. 2003, Radosevich *et al*. 2006, de Montigny and Nigh 2007, Bluhm, 2012), overwhelmingly the result of the damage to the unreplicated RA 8' treatment, and are thus, suspect.

To circumvent the effects of the abovementioned damage and to help make these results more useful for forest managers, relative yield values were calculated based on the PAVOL estimates of an undamaged, pure red alder stand, planted at the same density on a site of equal site quality. This volume estimate was obtained by using a general 3 year-old tree list and projecting 26 year-old PAVOL using RAP-ORGANON (Hann 2011). This projection resulted in 5534ft^3/acre vs. 2585ft^3/acre for the actual, damaged treatment.

Figure 15 shows RY by species and treatment. For red alder, RY was >1 for both of the mixed species treatments (2.17 for the 25%RA/75%RC and 1.22 for the 50%RA/50%RC) indicating that red alder volume growth was greater in the mixed species treatments as compared to the pure treatment. For redcedar, the results were the opposite: RY was <1 for both of the mixed species treatments (0.68 for the 25%RA/75%RC and 0.64 for the 50%RA/50%RC).

Relative yield total (RYT) by treatment is shown in Figure 16. RYT was 0.52 for the 25%RA/75%RC treatment and 0.46 for the 50%RA/50%RC treatment. These RYT values indicate a production penalty (<1) in these species mixtures (proportions) compared to pure stands of either species.

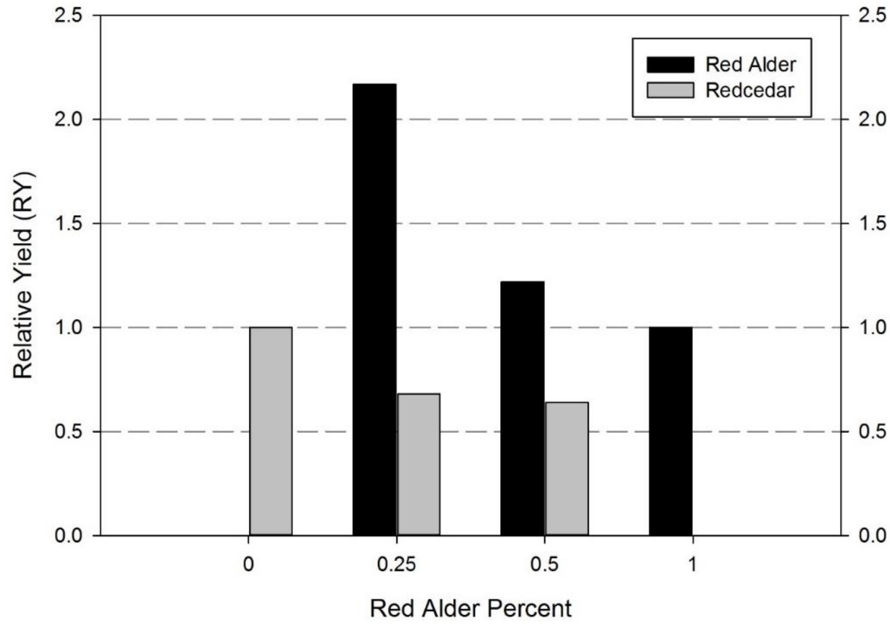


Figure 15- Relative yield (RY) by species and treatment for the Pilchuck Tree Farm red alder/redcedar replacement series experiment.

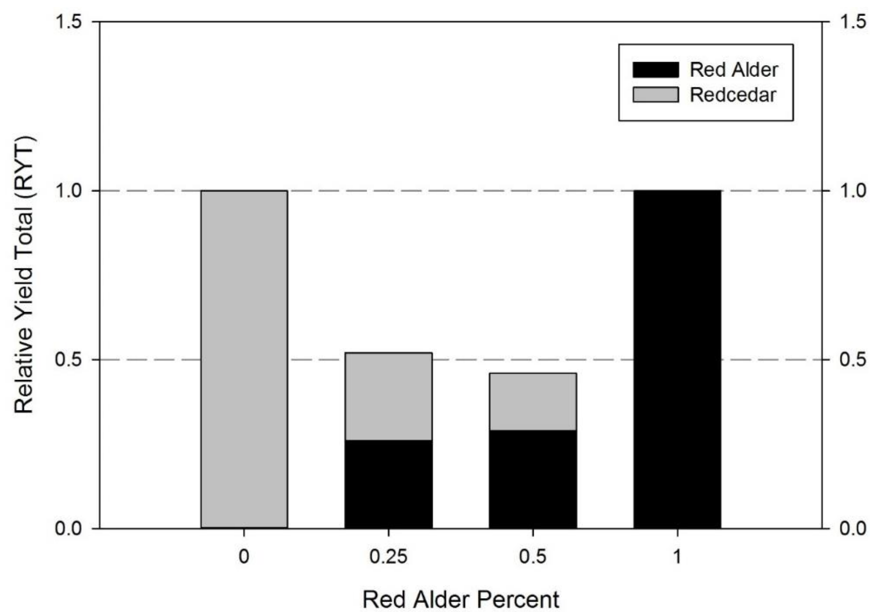


Figure 16- Relative yield total (RYT) and relative land output (b) by treatment for the Pilchuck Tree Farm red alder/redcedar replacement series experiment.

Using relative land output (RLO) as a measure of relative yield indicates an enhancement in productivity (>1) of mixed species treatments as compared to pure species treatments (Figure 17). RLO was 2.85 for the 25%RA/75%RC treatment and 1.86 for the 50%RA/50%RC treatment. Not only is this enhancement in productivity due to the large PAVOL values of the red alder in the species mixtures, but because there were minimal competitive effects on the understory redcedar (Forrester *et al*. 2006). These minimal competitive effects are in contrast to what is observed when Douglas-fir is grown with red alder in most mixed species situations (Radosevich, *et al*. 2006).

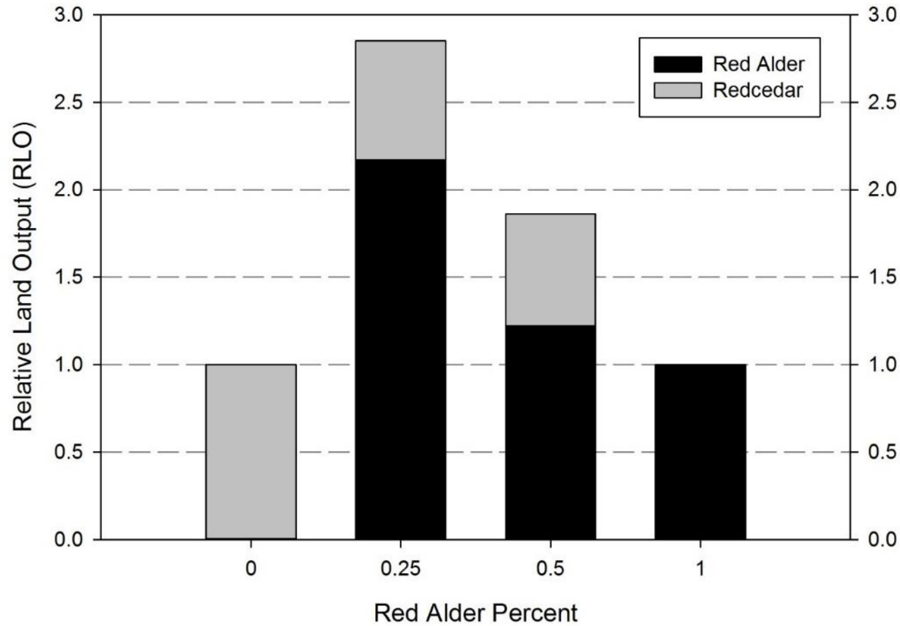


Figure 17- Relative land output (RLO) by treatment for the Pilchuck Tree Farm red alder/redcedar replacement series experiment.

Conclusion/Management Applications

There is warranted interest in mixed red alder–conifer stands in the Pacific Northwest. Reasons for this include the use of red alder to increase biodiversity or improve the growing conditions of conifers (*e.g*., replace artificial fertilization with nitrogen fixation on low-nitrogen sites), or the economic benefit of including a high value species. Nitrogen fixation can be a major objective for growing red alder in mixed species stands since it improves site productivity and sustainability on low-nitrogen sites. Because of its N-fixing ability, red alder can actually improve the growth of associated conifers on low-nitrogen sites, but in other cases it may lead to reduced growth compared with pure conifer stands (Binkley 2003). Also, mixing red alder into conifer stands seems to improve conditions for a variety of ecosystem functions (Deal and Wipfli 2004).

Therefore, under the right conditions, appropriate silvicultural practices can yield a production advantage from mixtures of red alder and conifer species (Khom and Franklin 1997). The time of establishment is critical because of the difference in growth pattern between red alder and associated conifer species. Red alder's fast initial height growth allows it to overtop all of its associated conifers (Harrington and Curtis 1986, Peterson *et al*. 1996). During this period, shade tolerant conifers such as redcedar can coexist in the understory. These redcedar will then act as "training trees," shading lower parts of the red alder crowns causing natural pruning (Stubblefield and Oliver 1978) and improving red alder wood quality (Grotta *et al.* 2004).

The shade tolerance of redcedar allows it to survive and continue growing slowly (Stubblefield and Oliver 1978, Minore 1990, Thomas *et al*. 2005). Surprisingly, in this study, the mixed species treatments had better survival of both red alder and redcedar than the pure, single species treatments. Furthermore, because this study was on a productive site, the reduced growth of the redcedar was expected. However, what was unexpected was the production enhancement of the red alder in the species mixtures.

The removal of the red alder should allow the redcedar to continue productive growth until the final harvest. Yet how much of the redcedar size, allometry, and yield is affected by the competitive effect of shading and by the facilitative effect of nitrogen fixation by the red alder remains unknown. This type of mixed species stand increases the logistical difficulty in management. Plans for harvest and removal need to be developed. During the harvest process, damage to the thin barked redcedar needs to be avoided from logging damage.

So, although the results here are only a case study and the amount of treatment replications were limited, the results show promise. Although the redcedar in the mixed species treatments suffered reductions in volume, this management scenario (or one like it) could have applications in forest management. First, in this scenario, the harvesting of the red alder at a rotation of 25 to 30 years would be economically profitable and second, the remaining redcedar after harvest should respond well (Cole and Newton 1986) and continue growing until its final rotation age. Third, although stand establishment costs would be higher in this scenario, not only are two crops produced, but no costs would incur from a precommercial thinning. This is a difficult area of study as mixedwood management in forestry is complex. However, there is a gradual acceptance of the idea that there is a place for silviculture management strategies which include mixes of red alder and redcedar.

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Outreach and Education

Red Alder Silviculture Workshop

On May 11, 2016, Peter Hurd with the NW Region of WA DNR organized and hosted an informal workshop for DNR foresters interested in red alder management. The day started with a tour of an old red alder thinning and western redcedar underplanting study. In this study, a 20 year old natural alder stand was thinned to various levels of basal area in 1998 with redcedar planted in 1999. Although no recent data exists for this study, it did provide a forum for discussing species mixtures. This discussion then led for Andrew Bluhm to discuss recent results and conclusions obtained from the HSC Type 3 species mixture experiments. After lunch, Andrew then led the group through the 26 year old HSC Type 2 installation Clear Lake Hill to look at and discuss the effects of stand management activities on red alder plantations.

Forest Owner Field Day

This workshop, sponsored by Washington State University Extension was held in Sequim, WA August 20, 2016. This educational event provided practical "how-to" information to a wide array of forest owners. This event included classes and activities led by experts in forest health, wildlife habitat, soils, fire protection, timber and non-timber forest products. Glenn Ahrens, director of the HSC taught the "Basics of Red Alder Management" and the "Advanced Hardwood Management" courses.

Clackamas Tree School

For the 27th year, OSU Extension Service put on the Clackamas Tree School. This huge event is an important part of the comprehensive OSU Extension education program. The 2017 Tree School offered 74 classes covering key topics to support successful management of diverse woodlands. Since Glenn Ahrens was busy organizing the event, Andrew Bluhm taught the class "Red Alder Management: Silviculture to Marketing" for the second year in a row. To a large (and inquisitive) audience, Andrew gave an overview of hardwoods in general and red alder in particular. He discussed why or why not to grow red alder, presented probable management or non-management scenarios and finished with topics about harvesting and marketing red alder.

Direction for 2018

As always, the HSC goals for 2018 are both the continuation of our long-term objectives and new topics and projects:

- Continue efforts to recruit new members.
- Continue HSC treatments, measurements and data tasks.
- Continue adding content and updating the HSC website.
- Continue efforts in outreach and education.
- Continue working with and analyzing the HSC data.
- Continue assisting HSC members with their specific red alder management needs and projects.
- Continue efforts at identifying the range of options available to create an easy-to-use growth and yield tool for red alder. Ideas range from a red alder stand table to refitting RAP-ORGANON using additional tree data from the HSC.

Appendix 1- HSC 2016 Committee Meeting Minutes

Thursday June 16, 2016:

The HSC 2016 Summer meeting was held in conjunction with the Washington hardwood Commission (WHC) Annual Symposium. This event titled "Experience an Alder Day in the Woods" toured operational, mid-rotation red alder plantations on Weyerhaeuser property in the Kelso & Ryderwood, WA area. Most aspects of operational red alder management were covered but special emphasis was placed on:

- Site productivity
- Site selection
- Plantation establishment
- Stand density management
- Commercial thinning

As part of the meeting, Glenn Ahrens spoke to the group about the HSC- its history, goals and importance to foresters and forestry in the PNW. In addition, Andrew Bluhm talked about stand density management using results from 22 year data from the HSC site #3202.
The tour was jam packed with information which is nicely assembled into a pdf found at the following: http://wahardwoodscomm.com/2016_AnnualMtg.html.

Friday June 17, 2016:

Attendees: Andrew Bluhm, Glenn Ahrens- OSU; Brian Morris- WA DNR; Michael Johnson- Hancock Forest Management /Washington Hardwood Commission; George McFadden- Bureau of Land Management; Florian Deisenhofer- Hancock Forest Management; Joe Monks- Northwest hardwoods/Washington Hardwood Commission.

The meeting started at 8:30 AM at the WA DNR Pacific Cascade Region Office in Castle Rock, WA with a welcome from the HSC program leader, Glenn Ahrens. As most are aware by now, Dave Hibbs has retired and Glenn has taken his place. The group then the highlights of the WHC tour from the day before. Discussion, here, centered on:

- Feasibility of commercial thinning
- Two site preparation treatments
- Seedling issues, specifically the lack of quality seedlings currently available
- Reduction of rotation ages

Next was a presentation given by Andrew Bluhm titled "HSC Red Alder Taper Project". This analysis was a continuation of the ongoing project investigating how well the red alder taper equation predicted DIB and thus volume. Andrew reviewed the previous results of "testing" the accuracy of the taper equation. Briefly, these are:

- DIB was most often under predicted above DBH
- DIB under predictions increased with increasing measurement point height
- Merchantable tree volume and log volume was consistently under predicted

This obviously raised the question whether the taper equation needed to be refit with using the now, much more robust dataset. To that end, the HSC in partnership with Aaron Weiskittel at the University of Maine evaluated the performance of the taper equation using the entire red alder taper database. The goal was to refit the Bluhm et al (2007) equation using the combined dataset and compare the performance of this new equation to an alternative model form and the existing equations. The (preliminary) results presented here showed that while the "new or refit" Bluhm equation did the best job at predicting diameter inside bark, the "old or original" Bluhm equation did the best job at predicting tree volume.

The group then discussed additional sources of taper data.

- Processor-gathered data
  - C & C logging
  - SE US pine processors
- Elochoman stands- old WeyCo density trial now owned by DNR

Andrew then moved on to HSC business with a review of last years' fieldwork, the coming years' fieldwork and an overview of the data collection schedule for all three installation types.

Last year (Winter 2015/16) had fieldwork on nine installations. Measurements included:

- Six Type 2 installations needed fieldwork.
- Humphrey Hill (4201, GYN) was the first installation receiving its 27th year measure.
- Five Type 2 installations- Lucky Creek (1202, BCMIN), Cape Mtn. (2204, SNF), Siletz (2205, Stimson), Dora (3207, BLM) and French Creek (4205, BCMIN) having their 22nd year measurement.
- Of these installations there was one pruning treatment (Lucky Creek) needed.
- Three Type 3 installations- Monroe-Indian (2301, Stimson), Turner Creek (4301, GYN), and Holt Creek (4303, BCMIN) having their 17th year measurement.

This upcoming year (Winter 2016/17) will have the "usual" amount of fieldwork with a total of six sites needing either a measurement or a treatment. Work will include:

- Two Type II installations- Clear Lake Hill (4202, GYN) and Ryderwood (3202, WHC) will have the 27th year measurement.
- Three Type II installations- Mt. Gauldy (2206, SNF), Scappoose (3209, BLM), and Darrington (4206, WADNR) will have the 22nd year measurement.
- Of these installations there will be one pruning treatment (Mt. Gauldy).
- One Type III installation- Menlo (3301, WADNR) will have the 17th year measurement.

As fall approaches, Andrew will contact each HSC member to provide specific on the activities and schedule the fieldwork. In theory, all sites have cooperator support, but depending on the status of Goodyear Nelson, there may not be a crew available to conduct the 27th year measurements on Clear Lake Hill. Therefore, it was decided for Andrew to stay in touch with Paul Kriegal, and if there is no support, to possibly have an HSC winter work party this coming winter to complete the measurements.

Next, Andrew presented the HSC budget. Highlights included:

- Dues received in 2016 were $47,500, down $5,000 from the year before.
- Actual costs, with the exception of Andrew's cost, were in line with what was projected.
- Therefore, with the increase in Andrew's costs and the reduction in revenue, Andrews's time was decreased from 0.40FTE to 0.35FTE.
- Looking ahead to 2017, and using the worst-case scenario in terms of dues income, Andrews's time will be decreased again from 0.35FTE to 0.30FTE.

After a break, the grouped discussed many topics including:

- Annual dues vs. project-based funding- inquire with Dave Hibbs and OSU accounting how flexible the mechanisms are to bring in "extra" or non-dues money
- Seedling availability
- Seed sources, relative performances, and climate change

- Clonal stock trial
    - WSU is developing some clonal material that may be available this fall
    - WSU and WeyCo are currently negotiating proprietary issues
    - Test sites for clonal stock- quantifying amount of gain
    - Seedling trials- bareroot vs. plug
    - Should the HSC coordinate test site selection, establishment, measurements, and data analysis? What would the time and cost be?
    - Hancock is very interested in this trial and already have a test site selected.
    - DNR and BLM could also provide test sites
    - Alex has the authority to share results from his clonal outplanting trial.
        - Realized gain trial
        - Planted in 2006 at 680tpa
        - 2 sites Westside of Coastal mountains
        - Appx. 12 clones and a local seed source/site
        - 6 reps, blocked by slope position, 40 trees/plot
        - Needs to be PCTd, could be done for free upon request
        - Would require measuring and maintenance
        - J&M has measured these sites in the past. Ask them for an estimate
        - Timeline- this winter?
- Mixed species and/or natural alder stand growth and yield model
    - Ask HSC members their degree of interest in a creating a new version of the plantation model vs. developing a mixed-specie/natural stand model.
- Mill trial for commercial thinned lumber
    - Randy Bartelt said this type of trial is easy and they are good at it but the right of 1st refusal HNW has with WeyCo would need to be addressed before Randy could buy a timber sale and do the mill study. Michael Johnson and Alex Dobkowski volunteered to take the lead on this effort
- WHC data request
    - Road Map
    - Deliverables
    - Proposal
    - HSC Member approval
    - Review RAP ORGANON validation
    - Stand tables

Appendix 2- HSC Financial Support 2017

Cooperator		Support
BC Ministry of Forests		$8,500
Bureau of Land Management		$20,000
Goodyear-Nelson Hardwood Lumber Company		$4,500
Hancock Natural Resource Group		$8,500
Oregon Department of Forestry		$8,500
Siuslaw National Forest		------
Washington Department of Natural Resources		$8,500
Washington Hardwood Commission		------
	Subtotal	$58,500
Oregon State University		$17,710
	Total	$76,210

Hardwood Silviculture Cooperative