Contents

Hardwood
Silviculture
Cooperative

Highlights of 2019

- Five more 27 year measurements were collected on the Type 2 installations (variable-density red alder plantation), bringing the total to 10 of the 25 installations with 27 year data.

- Three more 22 year measurements were collected on the Type 2 installations, so now all 25 installations have 22 year data.

- 23 of the 25 Type 2 installations have had all treatments completed.

- The last 22nd year measurement and the first 27th year measurement was completed on the seven Type 3 installations (red alder/Douglas-fir species mixtures).

- Additional field data on tree taper was collected:
    - 12 trees from the 27 year-old Shamu (ODF) Type 2 installation.

- The HSC and the Center for Intensive Planted-forest Silviculture (CIPS) updated RAP-ORGANON with additional, older tree data.

- The HSC participated in numerous continuing education and outreach events including: Clackamas Co. Tree School, the WA Farm Forestry Association (WFFA) Forest Owners Field Day, and the Washington Hardwood Commission (WHC) Annual Symposium.

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 website 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.

<u>Red Alder Stand Management Study</u>

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).

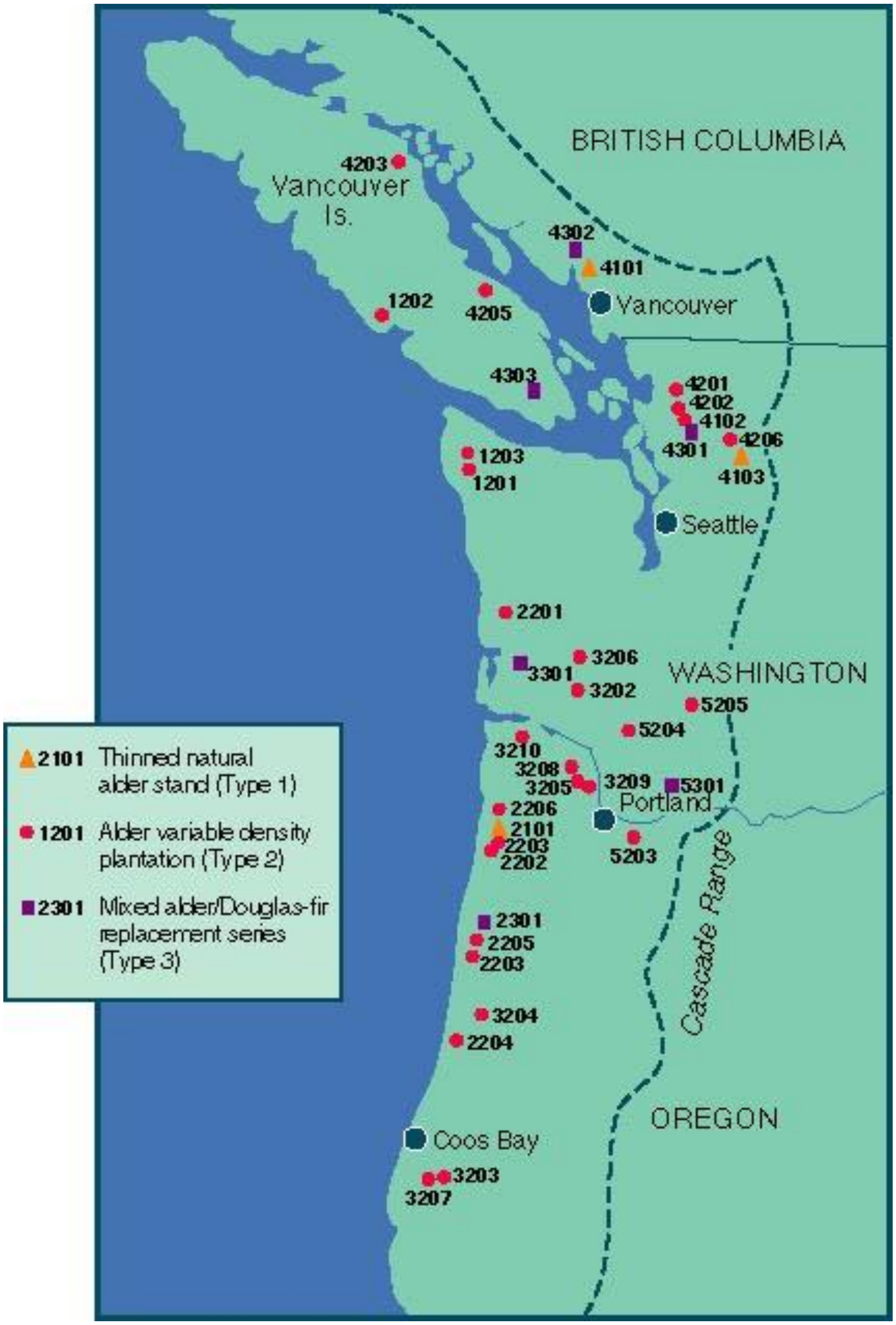

Figure 1. Location of installations for the Red Alder Stand Management Study.

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	2022	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 1 6ft	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 completed activities.

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 2018/19 measurements consisted of ten installations requiring field work (Table 5). Three sites had the 22nd year measurement (Weebe Packin, Wrongway Ck., Tongue Mtn.) and five sites had their 27th year measurement (Pioneer Mtn., Sitkum, Keller Grass, Shamu, Thompson Cat). One Type 3 installation had its 22nd year measurement (Puget) and one Type 3 installation had its 27th year measurement (East Wilson). No pruning or thinning treatments were required. There were two orphaned sites requiring fieldwork, a federal government shutdown, and plenty of low-elevation snow so scheduling and completing these measurements was difficult. Taper measurements on 12 trees were collected at the 27 year-old Shamu site.

Table 5. Hardwood Silviculture Cooperative Field Activities, Fall 2018-Spring 2019

Type	Activity	Installation	Cooperator
Type 1	Completed		
Type 2	22yr Measure	3208	ODF- Weebe Packin
		3210	OSU- Wrongway Ck.
		5205	GPNF- Tongue Mtn.
	27yr Measure	2203	ANE- Pioneer Mtn.
		3203	MEN- Sitkum
		3204	SNF- Keller-grass
		3205	ODF- Shamu
		5203	BLM- Thompson Cat
Type 3	22yr Measure	5301	GPNF- Puget
	27yr Measure	4302	BCMIN- East Wilson

So, in the big picture:

- All twenty five Type 2 installations have now had their 22nd year measurement.
- There are now ten Type 2 sites having their 27th year measurement completed.
- Twenty three of the twenty five Type 2 installations have all treatments completed.
- All seven Type 3 installations have had their 22nd year measurement.
- The first Type 3 installation has had its 27th year measurement.

This coming field season (Winter 2019/20) has nominal fieldwork (Table 6). Three Type 2 installations (Blue Mtn., Mohun Ck., Hemlock Ck.) will have their 27th year measurement. There are no thinning or pruning treatments required, nor any Type 3 measurements.

Table 6. Hardwood Silviculture Cooperative Field Activities, Fall 2019-Spring 2020

Type	Activity	Installation	Cooperator
Type 1		Completed	
Type 2	22yr Measure	Completed	
	27yr Measure	3206	WHC- Blue Mtn.
		4203	BCMIN- Mohun Creek
		5204	WHC- Hemlock Creek
Type 3		No Activities	

Current HSC Activities

Red Alder Clone Bank

The Hardwood Silviculture Cooperative, Washington Hardwoods Commission, and Hancock Forest Management launched an effort to establish a red alder clone bank, using material from Weyerhaeuser's tree improvement program, now housed at Washington State University. At this point, there are approximately 50 clones identified for the clone bank, however, WSU is planning to collect more data from test sites and possibly add to the number of clones for the clone bank.

Multiple locations were explored for the establishment of the clone bank including the J.E. Schroeder Seed Orchard (ODF), Webster Forest Nursery (WA DNR), Peavy Arboretum (OSU), the Travis Tyrrell Seed Orchard (BLM), and the Walter Horning Seed Orchard (BLM). The ODF Schroeder facility was chosen for several reasons: ODF has historically been an HSC cooperator and is a strong supporter of tree improvement and gene conservation, the location is fully integrated for tree improvement and has excellent facilities and knowledgeable staff, and the climate at the location is suitable for red alder.

The clone bank would preserve the improved genetics developed by the program and provide a source of vegetative material and/or seed for further propagation. A clone bank to hold the genetic material safely is ideal for the long term storage of the selections. However, to keep plants for production, material will also need to be stored as potted plants that are renewed every couple years. The exact number of clones (~50), raments per clone (~3-5), spacing (~10' x 10'), and the establishment (~$5,000/acre) and maintenance (~$700/acre) costs, and funding sources are currently being determined.

Red Alder Clone Trial

History

Clonal forestry in eucalyptus, poplar and other hardwood species have shown tremendous strides in improving wood properties and shortening rotation times. Therefore, a red alder clonal program would allow for the production of large numbers of plants that have been selected to exhibit specific wood characteristics coupled to improved growth. In 1997, Weyerhaeuser Hardwoods (then Northwest Hardwoods) initiated a clonal red alder program with the goal of delivering a clonal red alder propagation system to NW Hardwoods by using selected superior field material as the source material. The red alder clones were selected for the best form, growth, and characteristics suited to processing. Clones were tested for disease, frost, and drought tolerance. Much of this work was carried out at Weyerhauser's own facilities and also at facilities through Washington State University Research and Extension Center (WSU REC) located in Puyallup. In 2011 Weyerhaeuser sold the Hardwoods Division and gifted the Alder Program (under a variety of contractual obligations) to Washington State University Research Foundation (WSURF).

Initially, trees were selected (based on multiple criteria) from existing red alder plantations. Logs from these trees were brought to the lab and treated to initialize new growth. Then, cuttings were taken, rooted and become the parents for further testing. The parent plant is then topped and cuttings are taken from the branches.

These rooted cuttings were then placed out in replicated trials over multiple sites and years to assess the growth and tree form of the clones (Figure 2). Early results demonstrated significant gains in diameter (DBH) and height (HT) compared to unimproved (i.e. woods run) trees (Figure 3).

Figure 2. An example of a red alder clone trial after one growing season.

Clone	dbh gain	ht gain
clone 1	1.42	1.48
clone 2	1.34	1.16
clone 3	1.33	1.41
clone 4	1.33	1.18
clone 5	1.30	1.2
clone 6	1.29	1.19
clone 7	1.25	1.14
clone 8	1.24	1.39
clone 9	1.23	1.14
clone 10	1.23	1.14
clone 11	1.21	0.98
clone 12	1.19	1.16
clone 13	1.16	1
clone 14	1.16	1.36
clone 15	1.16	1.17
clone 16	1.13	1.21
clone 17	1.13	1.26
clone 18	1.12	1.2
clone 19	1.05	1.23
clone 20	1.04	1.33

top 10 clones	
dbh gain	ht gain
1.296	1.243

This means a 29.6% increase in DBH and a 24.3% increase in Height

top 20 clones	
dbh gain	ht gain
1.2155	1.2165

Figure 3. Early results of DBH and HT gain from the WSU red alder clone trials.

Objective

Although early trials indicate gains in growth, because of the contractual obligations, the specific clones and gain values are proprietary. Therefore, the objective of this study is to establish a clone trial on public land to compare the performance of approximately 14 red alder clones on the OSU Blodgett tract, plus a woods run control.

Clonal Material

The clones are produced by WSU as a continuation of the Weyerhaeuser Clonal Alder Program. In the original WeyCo program, clones were planted over a variety of sites, measured between age 5 &9, then ranked based on DBH gain, then height gain. Once clones displaying optimal gain were identified, other selection criteria (i.e. wood properties, disease tolerance, cold tolerance) were tested and assessed (Figure 4). In total, thirty-six (36) of the 648 clones were selected for production. WSU is currently providing clonal material for regional clone trials. Hancock currently has two of these trials planted on their Independence and Cathlamet tree farms.

Study Design

The trial will be planted in April 2020 in an unfenced area on the Newton Survivor unit on the Blodgett Forest (46.065472°, -123.344099°, 1060’). The area (~1.1 acres) will have been cleared of any slash piles, but the stumps and some slash will remain. The site will be hand sprayed and planted on a 9X9’ grid (537tpa), though this grid will be “less than perfect”, because planting spots will be somewhat constrained by stumps and slash. Clones will be rooted cuttings and grown in PSB 615A plugs. The woods run trees will be grown by PRT Hubbard from the 041 seed source (SW WA), bought from WA DNR. Seedlings are PSB 615A plugs.

The study design is a randomized complete block design with the number of blocks determined by the number of clones to be tested and the availability of material (ideally 25 blocks). Each block will contain 16 treatments: 14 clones plus a woods run control included twice (to account for its expected higher inter-tree variation). Blocks will be laid out in a serpentine fashion. Each treatment within each block is represented by an individual-tree plot, with planting locations randomly assigned. The trial will be surrounded by a minimum of two border rows of woods run control trees (Figure 5). All test trees, not including border trees, will be tagged with sequentially numbered aluminum tags placed on a wire pin on the south side of the tree. Tree #1 is located in the SW corner of the test site, with tags progressing North and going in a serpentine fashion.

Planned Data Collection

Initial tree size will be measured on either a) a subset of trees prior to planting, or b) all trees immediately after planting. Survival will be measured in year age 1 and 2. Tree size (height and diameter measurements) will likely be made in year 3, 6, 9, 12, and 17.

Figure 4. Thirteen year old trees from a WSU clone trial.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
20	D	P	M	H	L	G	C	E	D	H	O	A	K	M	F	P	L	F	H	D
19	F	A	L	J	B	H	M	P	B	C	I	M	C	O	A	N	C	A	E	J
18	G	N	E	C	A	D	K	O	F	J	E	N	E	H	I	L	O	M	B	K
17	O	K	B	I	I	F	J	N	P	K	G	L	B	D	G	J	G	P	N	I
16	L	N	G	J	C	N	P	J	N	J	D	M	K	A	M	E	H	J	E	K
15	A	M	F	E	G	H	O	B	H	B	A	O	D	C	H	G	P	B	N	I
14	K	I	D	P	E	M	K	F	E	L	P	C	L	B	F	J	C	A	F	G
13	C	B	O	H	I	L	D	A	F	G	I	K	O	P	N	I	L	M	O	D
12	N	F	M	A	H	A	G	D	I	N	F	O	E	J	A	I	H	G	N	J
11	O	P	G	H	P	I	J	L	C	H	G	B	M	C	P	B	O	L	K	P
10	C	L	I	D	F	K	B	N	K	P	D	J	O	D	G	K	C	F	D	I
9	E	J	B	K	E	M	O	C	L	M	E	A	F	L	H	N	B	E	A	M
8	A	P	J	K	M	D	O	H	O	I	L	N	C	P	K	J	G	J	N	B
7	F	D	G	L	E	B	P	A	E	D	C	J	F	D	M	I	E	A	O	H
6	M	O	H	E	L	K	N	G	P	K	A	B	B	L	H	G	F	I	K	L
5	N	B	I	C	F	J	I	C	F	M	H	G	N	E	A	O	P	C	D	M
4	I	A	O	B	F	E	I	H	D	L	K	G	I	A	B	O	C	J	P	G
3	H	G	C	J	K	J	M	B	O	A	H	C	K	H	E	D	I	H	B	N
2	M	E	P	D	L	P	N	A	E	B	N	I	N	F	G	C	D	E	A	M
1	F	N	K	L	O	G	D	C	J	P	F	M	P	M	J	L	O	F	L	K

Figure 5. Example of the red alder clone trial experimental design. Each color (and letter) is an individual seedling of a particular clone. There are 16 trees per block, 25 blocks, and a two tree wide woods run border.

Updates to the ORGANON Red Alder Plantation (RAP) Equations

Doug Mainwaring, David Hann, Andy Bluhm, Doug Maguire, David Hibbs, and Glenn Ahrens

Introduction

When the original red alder plantation version of ORGANON (RAP1) was first produced in 2011, the oldest measured data from red alder plantations were 18 years total age, so the initial version of the model was envisioned to provide suitably accurate extrapolations of trees and stands simulated out to 30 years, especially given the early peak of alder diameter and height growth. Comparison of model projections (using RAP1) to measured plot data from the HSC (Hardwood Silviculture Cooperative) network of plots has found some inconsistencies, most notably significant underestimates of diameter in thinned stands, and overestimates of mortality in unthinned stands.

A refit of updated datasets was made two years ago, when two of the installations had been measured at 28 years total age. Since that time, an additional 4 installations have received a 23-year measurement, 2 have received a 25-year measurement, and 8 have received a 28-year measurement, providing data applicable to trees and stands near an appropriate rotation age. CIPS (Center for Intensive Planted-forest Silviculture) allied with the HSC to refit the equations using the existing model forms, or, if necessary, with some simple alteration to existing equations.

This report provides a short description of the modeling dataset, provides results from refitting the equations, compares goodness of fit of the new and original equations to measured plot data, and presents results from applying the equations to a small validation dataset.

Dataset

The dataset for this work came from 23 Weyerhaeuser installations containing 239 separate plots and nearly 143,000 tree measurements, and from 25 HSC installations, containing 227 separate plots and 228,435 tree measurements. This dataset included over 70,000 more measurements than the dataset used for RAP1 fit, all of which came from HSC installations. Most importantly, the new dataset included completed measurements in all 23-year-old stands, and approximately 50% of the 28-year-old stands. Planting density ranged from a low of 70 TPA (trees per acre) to a high of 1749 TPA, with a median of 801 TPA. Thinning modifiers were based on nearly 200 plots subjected to thinning, with remeasurements ensuring that more than 50 plots had at least 10 years of growth since thinning and 15 had 15 or more years of growth response. Additional summary data are provided in Table 1.

An independent validation dataset was obtained for a thinning trial conducted in SW Washington. This trial, installed in an operational stand planted to ~600 TPA, consisted of a replicated set of 0.1 acre treatment plots, with each replication consisting of a control, and thins to 180, 240, or 300 TPA implemented at age 7 years. At age 13, all diameters and approximately 30 heights per plot were remeasured, including all heights on thinned plots. The original measurement did not include height to crown base measurements, necessitating an estimate of the initial values. SI_{20} estimates for each replicate (66.0, 75.2 ft) were based on age 13 height-age pairs on the control plot.

Table 1 Mean, maximum, and minimum dbh, height, and height to crown base (HCB) at 7 different ages in the red alder plantation database.

	mean			maximum			minimum		
Age	Dbh (in)	Ht (ft)	HCB (ft)	Dbh (in)	Ht (ft)	HCB (ft)	Dbh (in)	Ht (ft)	HCB (ft)
4	3.3	4.3	0.45	11.7	10.5	6.3	0.01	0.2	0
7	7.9	9.1	2.8	21.1	16.4	10	0.01	1.1	0
10	10.2	10.9	4.1	27	19.6	11.2	1	2.3	0
13	13	12.9	5.6	32	23.2	15.3	0.7	2.8	0
18	16.8	16.1	8.5	40.3	26.7	19.9	1.5	3.9	0.2
23	19.5	18.8	10.8	45.7	30.4	31.9	3.4	5.1	0.3
28	22.8	22.2	13.7	51	34.4	25.4	1.7	8.3	0

Height increment

Height growth was modeled as a function of potential height growth as represented by the top height or site tree component of the stand. For this purpose, a refitted Weiskittel et al. (2009) site index equation [1] was used to derive growth effective age based on the current estimate of site index (SI20; top height at 20 years) and the current height of the tree (Ht). The original Weiskittel et al. (2009) fit included only a small component of trees with a total age of 20 years, and although their results were based on a base-age invariant model form, it was decided to refit their published equation form with data from plots that met two criteria: 1) they had exceeded 20 years of age; and 2) they had been planted to 500 TPA or greater, i.e., at sufficiently high densities that dominant heights were free of a density effect (Hann et al. 2011). The resulting equation for predicting SI_{20} was:

[1] $SI_{20} = \mathrm{Ht40} \cdot \exp(-4.4582 * (20^{-0.5365} - (\mathrm{Age})^{-0.5365}))$

Potential height increment (PHI) for a given tree was estimated by algebraically isolating age in the above equation to determine its growth effective age (GEA), algebraically isolating Ht40 to determine the implied potential height of that tree at its GEA, and taking the difference between that height and the height of the tree at age (GEA +1). Height increment for each tree was then estimated by modifying this potential dominant height increment by accounting for relative dominance using a different model form than the original RAP ORGANON equation:

[2] $HtI = PHG \cdot a_0 \cdot (exp\left(a_1 \cdot CCH^{(a2+a3 \cdot CCH)} \cdot exp(1 - a_4 CR)\right))$

where *HtI* was predicted annual height increment (ft), *CCH* was crown closure at the height of the subject tree (expressed as a percentage), *CR* was crown ratio (expressed as a proportion), and a_0- a_4 were parameters estimated from the data (Table 2).

DBH increment

DBH increment was modeled with a function that potentially peaked over initial DBH. Similarly, variables representing the effects of stand density, relative social position, and site quality were included as predictors, specifically stand-level basal area, basal area in larger trees, crown ratio, and 20-yr site index ([1]). The following model was identified as the best predictor of diameter growth:

[3] $DI = exp(b_0 + b_1 \cdot ln(DBH + 1) + b_2 \cdot DBH + b_3 \cdot \ln\left(\frac{CR+0.2}{1.2}\right) + b_4 \cdot ln(SI_{20} - 4.5) + b_5 \cdot \left(\frac{BAL}{log(DBH+1)}\right) + exp(b_6 \cdot BA^{0.5}))$

where *DI* was predicted annual diameter increment (inches), *DBH* was initial diameter at breast height (inches), SI_{20} was the plot-level site index (ft at 20 yrs; equation [1]), *BAL* was basal area in larger trees (ft^2/ac), *BA* was total stand basal area (ft^2/ac), b_0-b_6 were parameters estimated from the data (Table 2), and all other variables were defined above.

Mortality

Parameters for an equation to predict the probability of mortality were annualized with a compound interest formula that was implemented iteratively (Flewelling and Monserud 2002). Predictor variables were set equal to their value at the beginning of the measurement period for each iteration. The iterative estimation process was run in SAS PROC NLIN and was allowed to continue until further changes in the parameter estimates resulted in no significant improvement in minimization of the negative log likelihood. The fitted model took the following form:

[4] $PM = \exp(Y)/(1+\exp(Y))$

[5] $Y = (c_0 + c_1 \cdot \log(DBH+1) + c_2 \cdot CR + c_3 \cdot BAL + c_4 \cdot SI_{20})$

where *PM* was predicted annual probability of mortality, c_0-c_4 were parameters estimated from the data (Table 2), and all other variables were defined above. Alternative models were assessed by comparing actual mortality rates to predicted rates in systematic subclasses of each of the independent variables. Final model selection was based both on the minimization of differences between actual and predicted mortality, as well as the interactive behavior of the mortality equation with the diameter growth and height growth equations as a prediction system.

Height to crown base

A static equation was constructed to update height to crown base over successive growth periods. The model was fitted using data from only those trees measured for both total height and height to crown base. The final model for undamaged trees, altered from the original ORGANON-RAP model form to remove the bias shown for trees with large HCB, was as follows:

[6] $HCB = (HT - K) / (X + K)$

[7] $X = (1 + exp(d_0 + d_1 \cdot HT + d_2 \cdot CCFL + d_3 \cdot ln(BA + 0.00001) + d_4 \cdot (DBH / HT^{d5}) + d_6 \cdot ln(SI_{20} - 4.5)))$

where *HCB* was predicted height to live crown base (ft), *CCFL* was crown competition factor in trees larger than the subject tree, d_0-d_6 were parameters estimated from the data (Table 2), and all other variables were defined above.

Diameter increment thinning modifier

Modifying equations are used within ORGANON to adjust individual tree growth in thinned stands to account for the differences in growth between those observed and those expected simply from reductions in stand density in unthinned stands. This effect of thinning that cannot be explained by the effect of lowering initial stand density proportional to the thinning is referred to as the direct effect of thinning. Following the procedures outlined for the production of such equations for the SMC variant of ORGANON (Hann et al. 2003), multipliers were developed to estimate the direct effects of thinning on both diameter and height growth.

The direct effect of thinning on red alder diameter growth was modeled as a function of thinning intensity, years since thinning, and crown ratio:

[8] DBH_{mod}=1+ $(e_1 \cdot PREM^{e2}) \cdot \exp(e_3 \cdot YST^2 + e_4 \cdot \mathrm{CR} + e_5 \cdot CR^2)$

where DBH_{mod} is the predicted multiplier, *PREM* is the proportion of basal area removed ($0<PREM<1$), *YST* is years since thinning, parameters e_1-e_5 were estimated from the data and all other variables were defined previously (Table 2).

Height increment thinning modifier

The direct effect of thinning on height increment was modeled as a function of thinning I tensity and time since thinning:

[9] HI_{mod}=1+ $(f_1 \cdot PREM) \cdot \exp(f_2 \cdot YST^2))$

where Ht_{mod} is the predicted multiplier, $f_1 - f_2$ were parameters estimated from the data, and all other variables are defined previously (Table 2).

Table 2 Parameter estimates and standard errors associated with equations [2], [3], [5], [7], [8] and [9].

	Parameter estimate	Standard error
[2] Height increment (MSE = 9.4020)		
a_0	1.077329	0.00311
a_1	-0.64738	0.0147
a_2	0.701689	0.0135
a_3	0.232774	0.0376
a_4	1.242131	0.0323
[3] Dbh increment (MSE = 0.1975)		
a0	-4.46403	0.0264
a1	0.342252	0.00928
a2	-0.07938	0.00177
a3	0.824363	0.00839
a4	1.0732	0.00641
a5	-0.01962	0.000146
a6	-0.07991	0.00103
[5] Mortality (MSE = 0.0294)		
c_0	-3.5989	0.0497
c_1	-4.3437	0.0232
c_2	-0.6214	0.0535
c_3	0.049	0.000356
c_4	0.0396	0.000635
[7] HCB (MSE = 13.7768)		
d_0	3.4935	0.0355
d_1	0.00608	0.00026
d_2	-0.00095	0.000017
d_3	-1.3064	0.00694
d_4	183.6	8.2917
d_5	0.0206	0.000228
d_6	1.8022	0.0121
K	1.2193	0.0173
[8] Dbh thinning modifier (MSE = 0.3369)		
e_1	0.0428	0.0168
e_2	0.4417	0.0753
e_3	-0.0181	0.00175
e_4	9.1595	1.4397
e_5	-9.278	1.3088
[9] Ht thinning modifier (MSE = 0.2646)		
f_1	-0.4312	0.0124
f_2	-0.0938	0.00964

Results and Discussion

The equation form for diameter growth was the same as that used for the original model (RAP-ORGANON), and only minor changes were made to the mortality equation, height to crown base equation, and the thinning modifier for height increment. The greatest changes were those to the height increment equation and the thinning modifier for diameter growth. The original effort to predict the direct effect of thinning, undertaken with much less time since thinning, found no significant direct effect of thinning on diameter growth (i.e., beyond the indirect effect imposed by reduction in initial stand density), though comparisons of thinned plots to model simulations found significant underestimation of diameter growth. With additional time since thinning and many more measurements, a diameter growth thinning modifier verified that thinning did result in a significant and positive direct effect on diameter growth (above that predicted by density reduction in the equation for unthinned stands) (Fig. 1). This positive effect was dependent on crown ratio, peaking for moderately-sized crowns. Presumably this reflects a greater relative improvement in light environment that is not experienced by a tree that already has a large crown, and by a tree with enough sun foliage and vigor to take advantage of the greater availability of light, water and nutrient resources. The new height growth modifier predicted a negative impact of thinning on height growth similar to the original equation in RAP-ORGANON (Fig. 1).

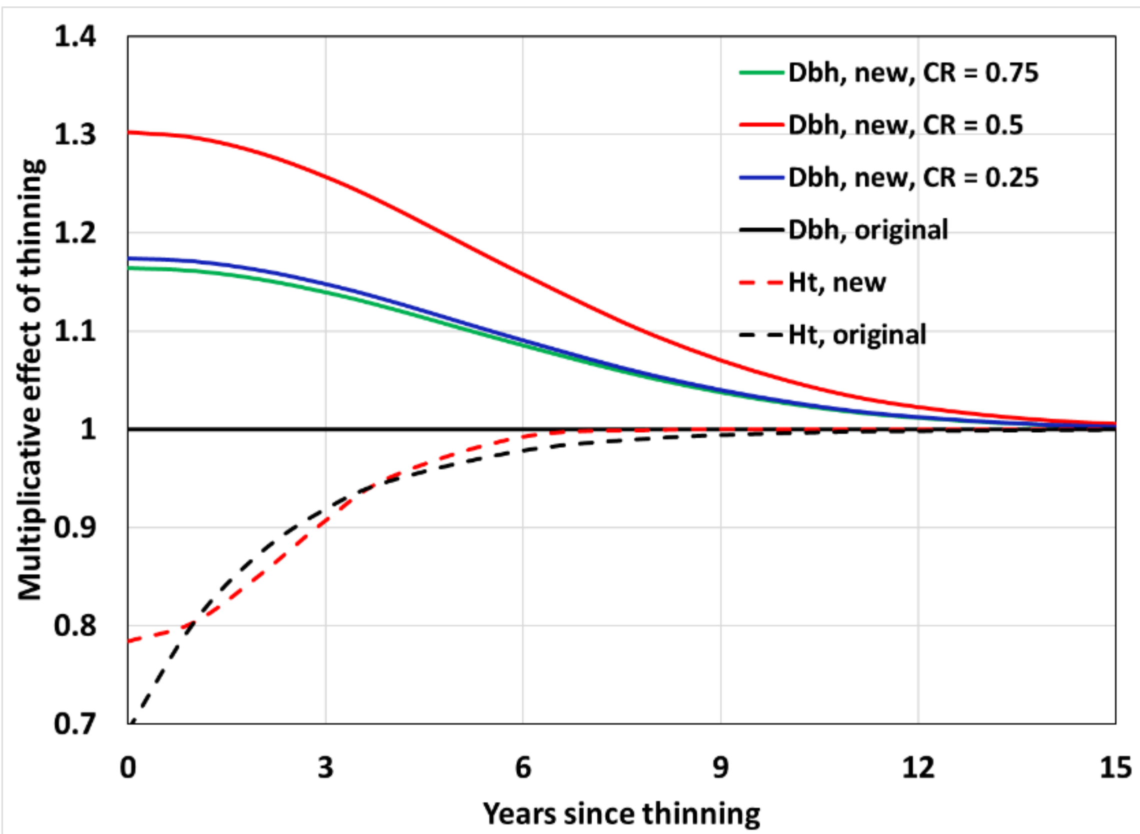

Figure 1. Modifiers for direct thinning effects on DBH and height growth of red alder in RAP-ORGANON (original) and new, under a thinning intensity that removes 50% of the basal area (PREM=0.50).

Comparisons between tree- and stand-level model-projections and the same variables measured or computed from measured treelists were made using both the original and new equations. For the control plots, the two model versions were used to project measured treelists over multiple projection periods (3-24 years) to compare projected values to measured values, thereby testing the performance of the growth projection system over time. For thinned plot comparisons, the two model versions were used to project measured treelists over the longest period over which measurements were available since time of thinning, with 95% of the plots having had at least 10 years of measured growth after thinning. On the tree level, results were presented as the mean periodic annual relative residual ((projected increment)/yr-(measured increment)/yr)/(measured increment/yr), and was further categorized by dbh quintiles, with quintiles 1-5 representing the largest 20% through the smallest 20% of the diameter distribution. On the stand level, results were presented as standing trees, basal area, cubic volume, or Scribner volume per acre. Periodic annual diameter growth on the control plots was generally more overestimated for larger trees and less underestimated for smaller trees with the new equations, while height growth estimates with the new equations provided a better fit (Figs. 2-3). Among thinned plots, the same general pattern was apparent for both diameter and height growth (Figs. 4-5).

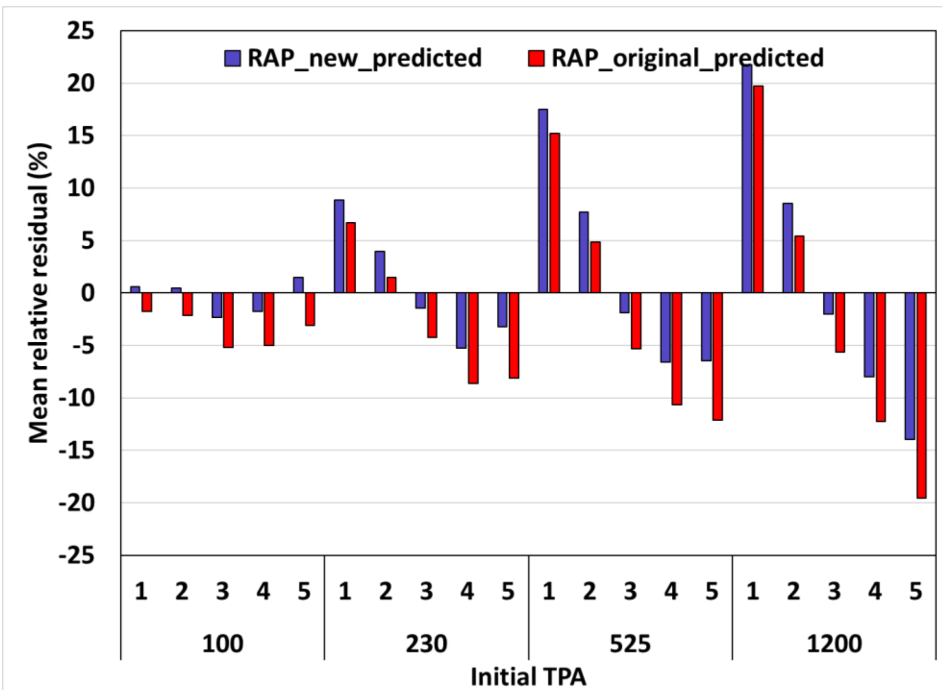

Figure 2. Mean relative periodic annual diameter increment residual by initial planting density and dbh quintile on control plots as predicted by the original and new RAP-ORGANON equations.

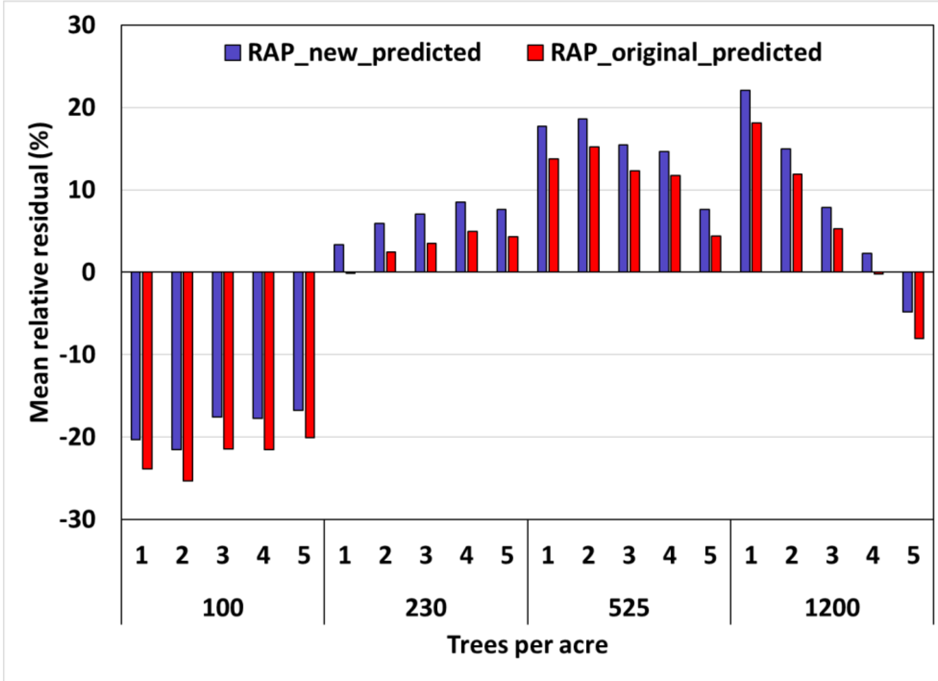

Figure 3 Mean relative periodic annual height increment residual by initial planting density and dbh quintile on control plots as predicted by the original and new RAP-ORGANON equations.

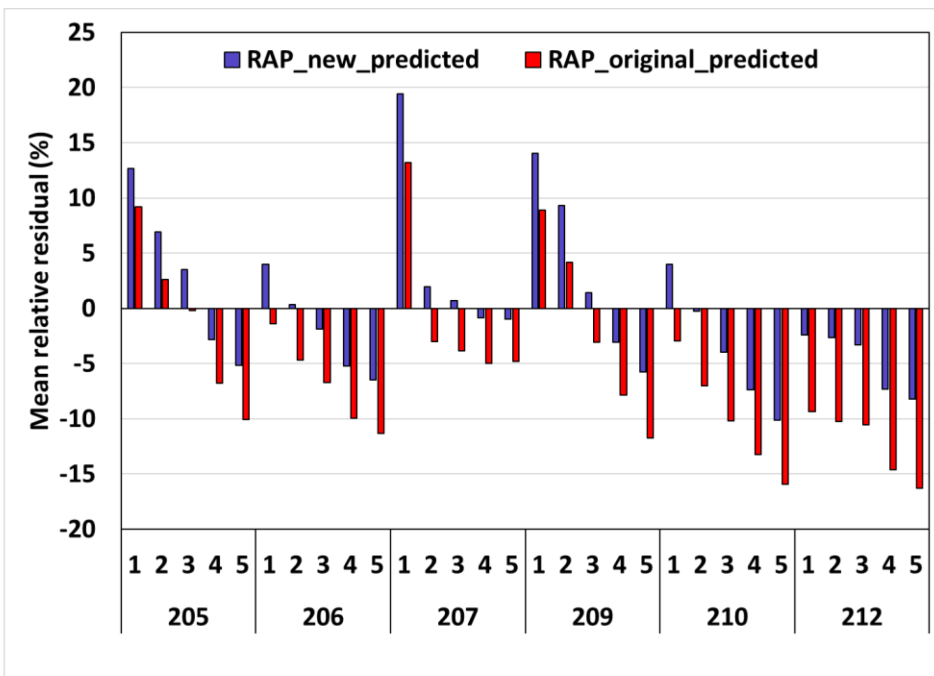

Figure 4 Mean relative periodic annual diameter increment residual by initial planting density and dbh quintile on thinned plots as predicted by the original and new RAP-ORGANON equations.

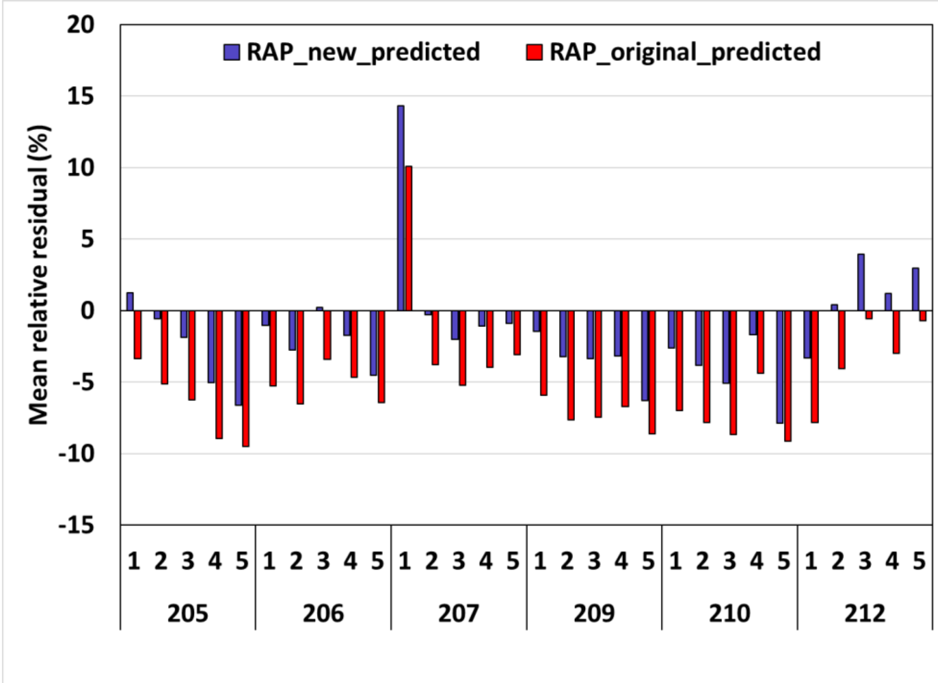

Figure 5 Mean relative periodic annual diameter increment residual by initial planting density and dbh quintile on thinned plots as predicted by the original and new RAP-ORGANON equations.

On the stand level, the new equations underpredicted standing TPA, BA and volume on both control and thinned plots, though the new fits are an improvement relative to the original equations. Importantly, given the identified shortcoming in the predicted diameter increment response to thinning, the difference between the measured values and the predicted values on thinned plots are greatly diminished using the new equations, with average standing Scribner volume underestimated by 7.6 and 3.0% on control and thinned plots with the new equations, versus 17.2 and 22.5% with the original equations respectively on the same plots (Figs. 6-7).

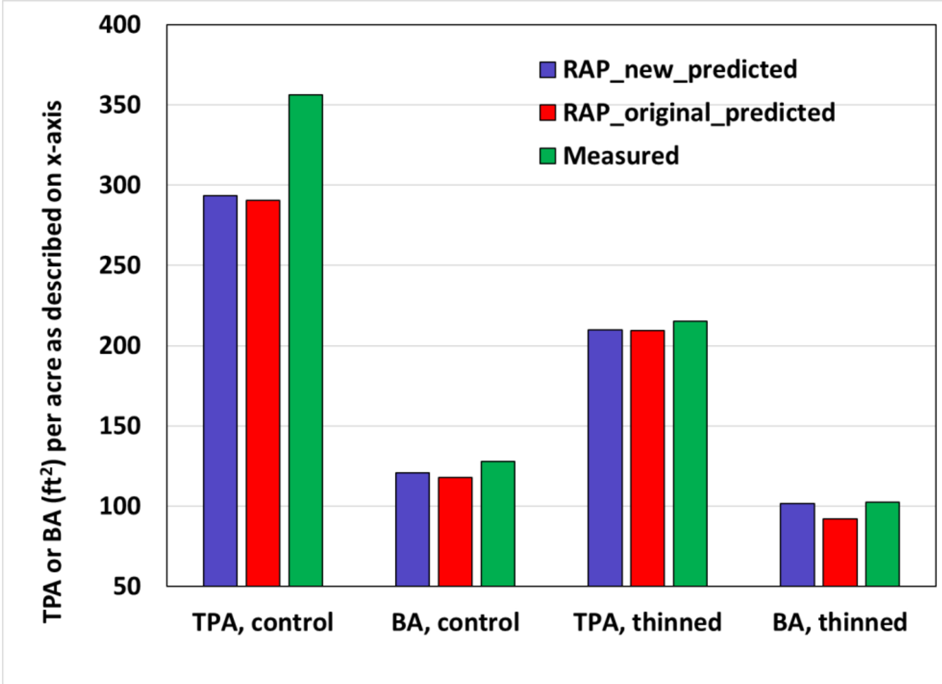

Figure 6 Predicted (using original and new RAP-ORGANON equations) and measured standing trees per acre and basal area per acre on the control and thinned plots averaged across all treatments.

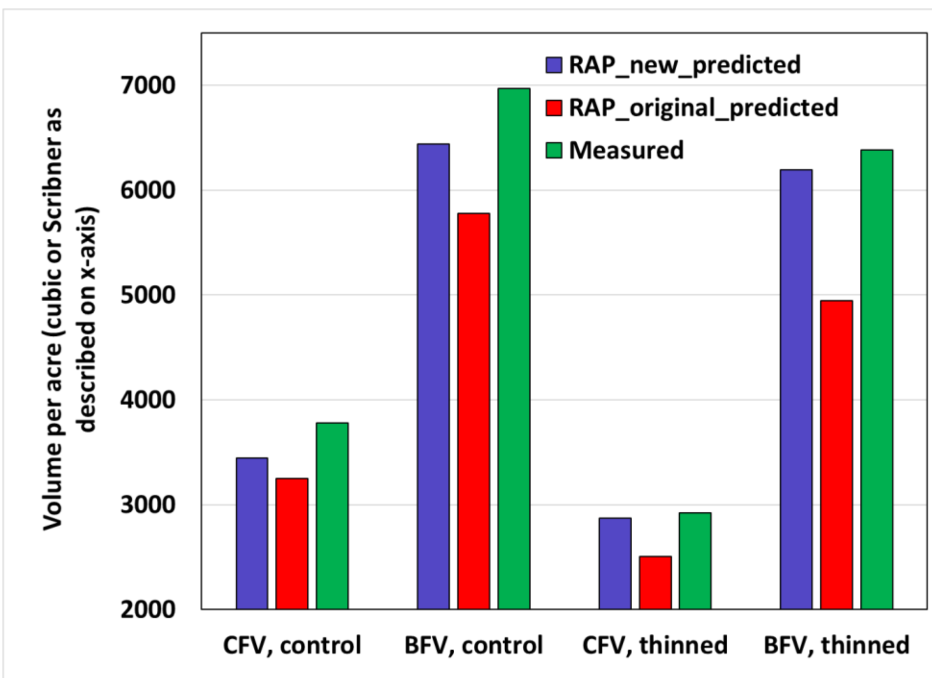

Figure 7 Predicted (using original and new RAP-ORGANON equations) and measured standing cubic and Scribner volume per acre on the control and thinned plots averaged across all treatments.

An independent validation dataset was obtained for a thinning trial conducted in SW Washington. This trial, installed in an operational stand planted to ~600 TPA, consisted of a replicated set of 0.1-acre treatment plots, with each replication consisting of a control, and thinnings to 180, 240, or 300 TPA implemented at plantation age 7 yrs. At age 13, all diameters and approximately 30 heights per plot were remeasured, including all heights on thinned plots. The original measurement did not include height to crown base, necessitating an estimate of the initial values. SI_{20} estimates for each replicate (66.0, 75.2 ft) were based on age 13 height-age pairs on the control plot.

Diameter and height increment residuals were calculated for projections using the new equations, comparing each value to the measured growth over six years. The combined results for the two replicates show that the original equations underpredict diameter growth on both sites, with underpredictions increasing with density reduction (Fig 8). Height growth was overpredicted on each plot, with overpredictions varying from 2-3.5 feet over 6 years (Fig 9). Although these results are do not show a particularly good match, the short duration of the growth period and the variability of the site index estimates over such a small area suggest that this small-scale validation may not provide the final word as to the quality of the new fits.

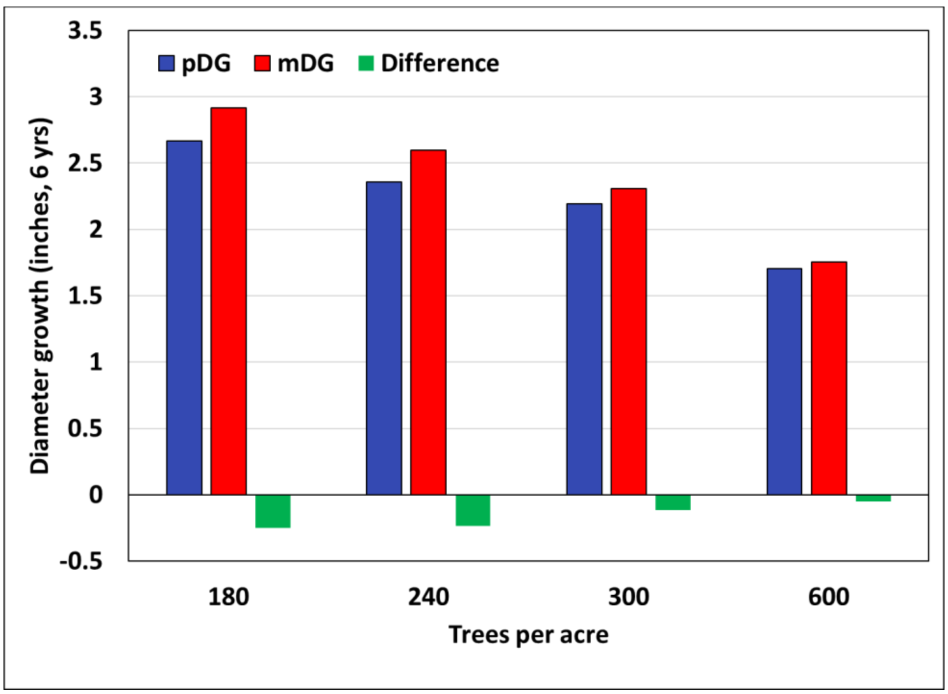

Figure 8 Predicted (using new RAP-ORGANON equations) and measured absolute diameter growth over six years on the four treatments of the Shakers thinning trial.

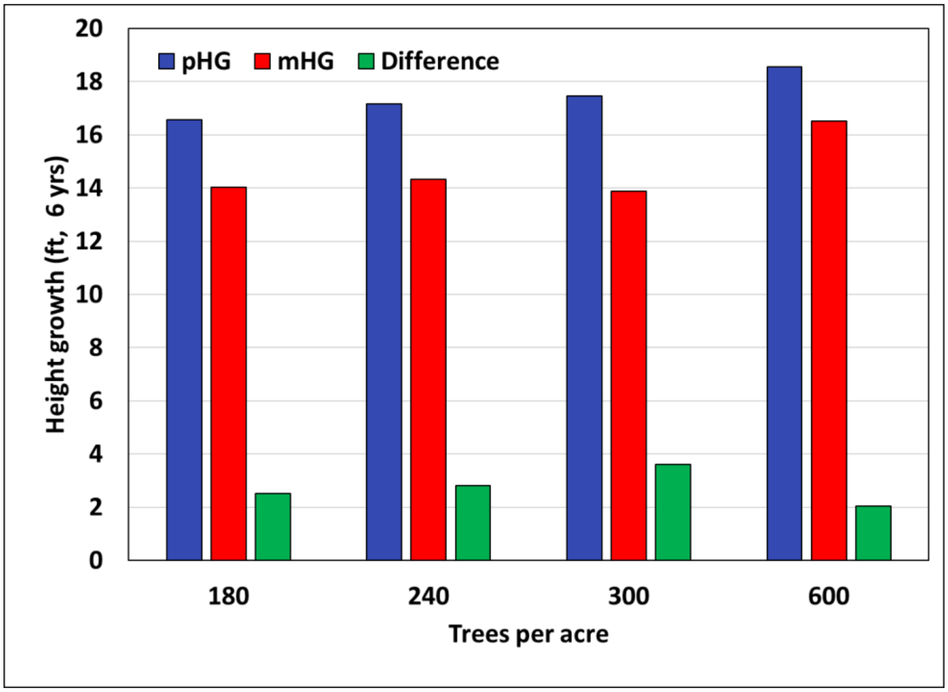

Figure 9 Predicted (using new RAP-ORGANON equations) and measured absolute height growth over six years on the four treatments of the Shakers thinning trial.

Literature cited

Flewelling, J.W. and R.A. Monserud. 2002. Comparing methods for modeling tree mortality. Pp. 169-177 in N.L. Crookston and R.N. Havis (Editors). *Proceedings of the 2nd Forest Vegetation Simulator Conference (RMRS-P-25),* USDA Forest Service.

Hann, D. W., D. D. Marshall, and M. L. Hanus. 2003. Equations for predicting height-to-crown-base, 5-year diameter-growth rate, 5-year height-growth rate, 5-year mortality rate, and maximum size-density trajectory for douglas-fir and western hemlock in the coastal region of the pacific northwest. Forest Research Lab., Oregon State University, Corvallis, Oregon. Research Contribution 40. 83p.

Hann, D.W., Bluhm, A. and Hibbs, D.E. 2011. Development and evaluation of the tree-level equations and their combined stand-level behavior in the red alder plantation version of ORGANON. College of Forestry, Oregon State University, Corvallis, OR. Forest Biometrics Research Note 1.

Weiskittel, A.R., Hann, D.W., Hibbs, D.E., Lam, T.Y. and Bluhm, A.A. 2009. Modeling top height growth of red alder plantations. For. Ecol. Man. 258:323-331.

Outreach and Education

WHC Annual Symposium

Glenn Ahrens, director of the HSC, was invited to present on the "Future of Red Alder Management on Private Woodlands at the Washington Hardwoods Commission Annual Symposium on June 14, 2018 in Puyallup, WA. Glenn Explained recent trends showing an overall decline in hardwood timber supply from private lands and discussed key factors behind the trends and priorities for future efforts to sustain hardwood resources in the Pacific Northwest.

Andrew Bluhm also was invited to discuss the "Development of New Red Alder Management Tools" including new site index equations, site selection tools, volume equations and volume tables, and the updated growth and yield model (65 people).

WA Family Forest Field Day

This workshop, sponsored by Washington State University Extension was held in Woodland, WA August 18, 2018. 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 "Red Alder and Hardwood Management" (60 people).

Washington Farm Forestry Association- Lewis County Chapter

On August 21, 2018, the Lewis County chapter of the WFFA had a "Twilight Tour" of the Weyerhaeuser/HSC Ryderwood red alder plantation. Andrew Bluhm led the tour, and presented information on the silviculture and growth of this site, in particular, and red alder stands, in general.

Clackamas Tree School

On March 23, 2019, OSU Extension Service put on the 29th Annual Clackamas Tree School at Clackamas Community College, OR. This one day event was for family forestland owner, forester, loggers, arborists, teachers and the general public. This event offered 75 classes covering key topics to support successful management of diverse woodlands. Andrew Bluhm taught the class “Red Alder Management: Silviculture to Marketing” to a small but inquisitive audience. 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. Andrew also taught the course “Hand Tools Can Be the Best Tools” which covered the use, maintenance, and repair of the various tools used in forestry.

Direction for 2020

The HSC goals for 2020 are the continuation of our long-term objectives and new projects:

Long-term:
- 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.

Short-term
- Test and publish the GIS based red alder site selection tool.
- Test and make public the updated version of RAP-ORGANON.
- Create user-friendly, red alder stand tables from the updated RAP-ORGANON growth and yield model.
- Establish red alder clone bank.
- Establish red alder clone trial.

HSC 2018 Committee Meeting Minutes

Friday June 15, 2018:

Business Meeting

Attendees: Andrew Bluhm, Glenn Ahrens- OSU; Brian Morris- WA DNR; Florian Deisenhofer- Hancock; Dave Sweitzer- Washington Hardwood Commission; George Harper- BC Ministry of Forestry; Darrel Alvord- Cascade Hardwoods

The meeting started at 8:30 AM at the DNR Castle Rock, WA office with a welcome from the HSC program leader, Glenn Ahrens. After welcomes, Andrew Bluhm 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 2017/18) had six installations requiring field work:

- Two more of the oldest HSC sites (LaPush and Pollard Alder) had their 27th year measurement.
- One Type 2 installation (Maxfield) and one Type 3 installation (Cedar Hebo) had their 22nd year measurement.
- In addition to the above measurements, two installations required thinning (Dora and Cape Mtn.) and two installations were due for the 4th and final pruning lift (Cape Mtn., and Maxfield).
- There were no orphaned sites due for measurement or treatment.

Next year (Winter 2018/19) will be a busy year.

- Five Type 2 installations (Pioneer Mtn., Sitkum, Keller-Grass, Shamu, and Thompson Cat) will have their 27th year measurement.
- Three Type 2 installations (Weebe Packin, Wrongway Ck., and Tongue Mtn.) will need their 22nd year measurement.
- One Type 3 installation (East Wilson) will have its 27th year measurement.
- There are no thinning or pruning treatments required.
- Unfortunately, three of the ten installations are "orphaned" making it difficult to get the measurements completed.

As fall approaches, Andrew will contact each HSC member to provide specific on the activities and schedule the fieldwork.

Next, Andrew presented the HSC budget. Please see the handouts included in the meeting folder. Highlights included:

- Dues received in fiscal year 2018 were $55,572, very similar to the dues received the year before.
- Actual FY2018 costs (with the exception of increased supplies and travel costs) were in line with what was projected for FY2018.
- Andrew's time remained at 0.35FTE.
- The HSC will be carrying over appx. $61,000 into FY2019.

- Starting in 2019, ODF will no longer be a dues paying member, other than that, FY2019 dues paying members should remain the same.
- Because of the workload and availability of carryover funds, Andrews's time is projected to increase to 0.40FTE.

Discussion about the HSC budget and future direction covered several key topics:

We discussed strategies to increase membership/dues such as revisiting hardwood industry entities and major landowners with renewed effort to encourage membership in and support for HSC.

We highlighted HSC's ongoing collaboration with the Center for Intensive Plantation Silviculture (CIPS). This effort has produced an update of the Red Alder Plantation (RAP) growth and yield model equations using HSC data collected from 22- and 27-year-old installations, a great improvement on the earlier RAP version. This will allow us to proceed in using RAP to develop products such as yield tables and projected outcomes from likely management scenarios that foresters and landowners can use to guide their decisions. Given that red alder is the third most abundant commercial tree in western Oregon and Washington, we are pursuing increased attention to red alder from CIPS.

Also, a key topic was the possibility for HSC to pursue establishing a clone bank and/or a seed orchard using material from the WSU alder clone program we learned about at the Washington Hardwoods Commission symposium on June 14.

Field Tour

Attendees: Andrew Bluhm, Glenn Ahrens- OSU; Brian Morris- WA DNR; Florian Deisenhofer- Hancock; Dave Sweitzer- Washington Hardwood Commission; George Harper- BC Ministry of Forestry; Ken Jones- Cascade Hardwoods; Josh Himsl & Patrick Shults- NRCS; Randy Roeh- Hancock; Jeremy Martin- Northwest Hardwoods; Matthew Provencher- WA DNR; Tom & Bryan Inglin; Frank Curtin; Chuck Lorenz.

Starting at 10:30, we all grouped up, drove to the Longview, WA/Abernathy Creek area and toured some of DNRs red alder plantations. Below is a list of tour stops and the associated topics of interest.

- Stop #1- Cant Dog U1; Harvest 2017, site prep 2018, plant red alder 2019
    - Site Selection
    - Seedlings

- Stop #2- Other Side U2; Harvest 2005, site prep 2006, plant red alder 2007; PCT 2013
    - PCT Timing & Density
    - PCT Economics

- Stop #3- Sprawlder; 20 year-old, operational red alder plantation
    - Stand Trajectories
    - Desired Log Sizes & Quality

- Stop #4- Sprawl; 30 year-old research unit (SI20=74.7ft)
    - Density management effects on tree form
    - Density management effects on stand volume
    - Red alder vs. Douglas-fir Economic comparison

WA DNR Operational red alder plantation- 20 years old

HSC Financial Support 2019

Cooperator	Support
BC Ministry of Forests	$8,500
Bureau of Land Management	$8,500
Goodyear-Nelson Hardwood Lumber Company	$4,500
Hancock Natural Resource Group	$8,500
Oregon Department of Forestry	------
Siuslaw National Forest	------
Washington Department of Natural Resources	$8,500
Washington Hardwood Commission	------
Subtotal	$38,500
Oregon State University	$11,165
Total	$49,665