HSC

Hardwood Silviculture Cooperative

2009 Annual Report

Staff

David E. Hibbs

Professor

Program Leader

Email: david.hibbs@oregonstate.edu

Andrew A. Bluhm

Associate Program Director

Email: Andrew.Bluhm@oregonstate.edu

Department of Forest Science

College of Forestry

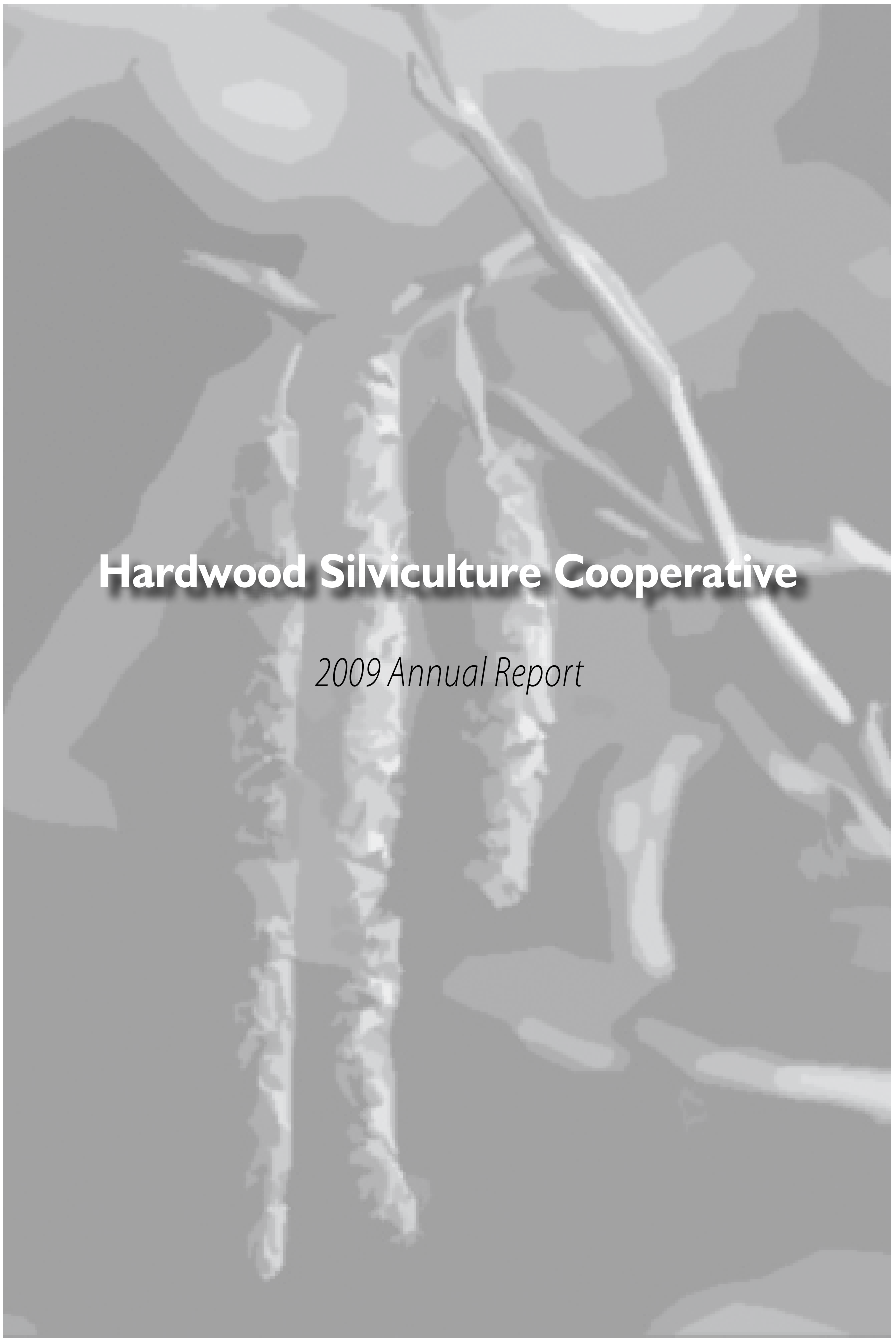
321 Richardson Hall

Oregon State University

Corvallis, OR. 97331-5752

(541) 737-6100

www.cof.orst.edu/coops/hsc/



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Highlights of 2008-2009

- A dominant height growth equation for plantation-grown red alder was developed based on repeated measures of stand-level top height. This equation, which can be used to predict site index differed appreciably from previous dominant height growth equations.

- The ORGANON modeling effort is continuing. Many of the equations necessary for the functioning of the model have been completed.

- All HSC Type 3 sites have had at least the 12th year growth measurement.

- All 26 of the Type 2 sites have had at least the 12th year growth measurement.

- Five more of the Type 2 sites have had the 17th year growth measurement, making a grand total of 11 (of the twenty six) sites with seventeen year data.

Hardwood
Silviculture
Cooperative

Contents

HSC Executive Summary 2009

Established in 1988 by a small and visionary group, the HSC is in the lead developing and providing information for foresters interested in red alder management. The progress in 20 years is quite amazing to contemplate

The HSC has established thirty-six study installations spread from Coos Bay, Oregon to Vancouver Island, British Columbia. There are three study types:

- 4 thinning studies in natural red alder stands
- 7 replacement series studies of red alder/Douglas-fir mixtures
- 26 variable density red alder plantations with thinning and pruning treatments

Last year's data collection schedule was extensive and notable. The three youngest plantations had their 12th year measurement- so now all of the plantations are at least 12 years old. Furthermore, 5 sites had their 17th year measurement bring the grand total of sites with 17 year data to 11. In addition, all of the replacement series sites are at least 12 years old.

This data is being added to the already massive amounts of data that have been (and still are being) collected, creating an impressive database unprecedented in the PNW. Only Douglas-fir has a stronger data base.

These data are currently being used to develop a growth and yield model for red alder plantations (RAP-ORGANON), an essential tool for the management of red alder. This model will provide much needed information to estimate site productivity, growth responses following thinning, and the extrapolation of stand volume, rotation ages, log sizes, etc.

So far, in the process of developing RAP-ORGANON, equations to predict height-diameter relationships, maximum crown width, largest crown width, crown profile, and height to crown base have been created. Diameter and height growth rate equations are currently being developed.

Furthermore, the value of the HSC data and study design is being recognized by researchers who are interested in a number of forestry related topics. These include:

- A collaborative effort led by Aaron Weisekittel (University of Maine) and David Hann (OSU) has led to the creation of dominant height growth equations for plantation-grown red alder. This equation can be used to predict site index (and thus site productivity) for red alder plantations across a range of different growing conditions and ages.
- Tzeng Yih Lam (OSU) along with Andrew Bluhm has just started a project using the HSC database to investigate the effects of stand density on the growth of red alder plantations. Results of this effort could have significant impacts on management decisions.
- Peter Kennedy (Lewis and Clark College) used the HSC Type 2 installations to study the effects of geographic location, stand origin, and tree density on nitrogen-fixing *Frankia* populations.
- A Canadian group led by Louise de Montigny (B.C. Ministry of Forests) has submitted a proposal that would use the HSC Type 3 installations in a study of species interactions and climate change.

Abstracts and summaries of these research projects are presented here.

Managing red alder stands has finally gained acceptance in part due to the efforts of the HSC and all of its members. Whoever would have thought that back at the inception of the HSC the idea of alder management would be so popular today? The vision of a small and dedicated group has made managing red alder no longer a dream but a reality.

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 (*Pseutotsuga menzeisii*) 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 can 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 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://www.cof.orst.edu/coops/hsc 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 a red alder growth model.

The HSC red alder stand management studies are well designed and replicated on a scale rarely attempted in forestry. Over the next 10 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.

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

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). 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 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.

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).

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 what activities have been completed and illustrate the tremendous accomplishments of the HSC to date.

Winter 2008/09 had a considerable amount of fieldwork. Measurements and various treatments were completed on 11 of the 36 installations (see Table 5). Many thanks go out to all of the cooperators for providing crews and a special thanks goes out to the HSC Management Committee, for measuring the orphaned Type 2 installation #3203 (Sitkum). Last years work included:

- One Type 1 installation was measured.
    - Battle Saddle had its 19th year measurement. This is the 2nd of the 4 Type 1 installations with 19 year post-thinning data.
- Eight Type 2 installations had fieldwork.

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

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

Definition of Acronyms

1. ANE-ANE Hardwoods
2. BCMin-British Columbia Ministry of Forests.
3. BLM-Bureau of Land Management.
4. DNR-Washington Department of Natural Resources.
5. GYN-Goodyear-Nelson.
6. GPNF-Gifford Pinchot National Forest.
7. MBSNF-Mt. Baker Snoqualmie National Forest
8. MEN-Menasha
9. ODF-Oregon Department of Forestry.
10. OSU-Oregon State University Forest Research Laboratory.
11. SNF-Siuslaw National Forest.
12. WHC-Washington Hardwood Commission.

- Three sites- Weebe' Packin', Wrongway Creek, and Tongue Mtn. had their 12th year measurement and either a pruning (Weebe' Packin') or the 2nd thinning treatment (Wrongway Creek and Tongue Mtn.).
- Five sites had their 17th year measurement and appropriate treatment: Pioneer Mtn. (3rd thinning and 4th pruning lift), Keller-Grass (3rd pruning lift), Shamu, and Thompson Cat (4th pruning lift). All treatments are completed on 8 of the 11 sites with 17 year data.

▼ Two Type 3 installations had fieldwork.

- Puget had its 12th year measurement. This was the last Type 3 to have its 12 year measurement.
- East Wilson had its 17th year measurement. This was the first Type 3 to have its 17th year measurement.

This coming year's fieldwork (Winter 2009/10) is greatly reduced compared to last year. A total of 6 installations need either a measurement or a treatment. See Table 6

Table 2. 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	1990	1991	1991	1991	1992	1992	1993	1993	1993	1993	1993	1994	1994
2nd yr Regen	1991	1992	1992	1992	1993	1993	1994	1994	1994	1994	1994	1995	1995
Plot Installation	1992	1993	1993	1993	1994	1994	1995	1995	1995	1995	1995	1996	1996
3rd yr Measure	1992	1993	1993	1993	1994	1994	1995	1995	1995	1995	1995	1996	1996
3-5 yr Thin	1993	1996	1996	1994	1996	1996	1997	1998	1997	1997	1996	1998	1998
Prune Lift 1 6ft	1995	1996	1996	1996	1996	1996	1997	1998	1997	1997	1996	1998	1998
6th yr Measure	1995	1996	1996	1996	1997	1997	1998	1998	1998	1998	1998	1999	1999
15-20' HLC Thin	1995	1999/07	1999	1996	1999	1999/02	2000	2001	2001	2000	2000	2002	2001/03
Prune Lift 2 12ft	1995	2002	1999	1996	2002	2000	2000	2001	1999	2000	2000	2002	2002
9th yr Measure	1998	1999	1999	1999	2000	2000	2001	2001	2001	2001	2001	2002	2002
Prune Lift 3 18ft	1998	2010	2002	1999	2008	2003	2004	2001	2009	2004	2004	2002	2007
12th yr Measure	2001	2002	2002	2002	2003	2003	2004	2004	2004	2004	2004	2005	2005
30-32' HLC Thin	2001	2012?	NA	2002	2011	2008	2009	2004	NA	2007	2009	2007	2010
Prune Lift 4 22 ft	2001	2012?	2002	2002	2013?	2008	2009	2004	2014	2007	2009	2005	2010?
17th yr Measure	2006	2007	2007	2007	2008	2008	2009	2009	2009	2009	2009	2010	2010
22nd yr Measure	2011	2012	2012	2012	2013	2013	2014	2014	2014	2014	2014	2015	2015

Table 2 continued

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	1994	1995	1995	1995	1995	1995	1996	1996	1996	1997	1998	1998	1998
2nd yr Regen	1995	1996	1996	1996	1996	1996	1997	1997	1997	1998	1999	1999	1998
Plot Installation	1996	1997	1997	1997	1996	1996	1997	1998	1997	1998	2000	2000	2000
3rd yr Measure	1996	1997	1997	1997	1997	1997	1998	1998	1998	1999	2000	2000	2000
3-5 yr Thin	1998	1999	1999	1999	1999	1999	2001	2000	2000/01	2002	2003	2003/06	2003/07
Prune Lift 1 6ft	NA	1999	1999	1999	NA	1999	2001	2000	2000	2002	2003	2003	NA
6th yr Measure	1999	2000	2000	2000	2000	2000	2001	2001	2001	2002	2003	2003	2003
15-20' HLC Thin	2002	2006/08	2006	2003/06	2003	2003/11	2004/07	2004/07	2002/07	2005/08	2007/12	2007/09	2009/12
Prune Lift 2 12ft	NA	2006	2003	2003	NA	2003	2004	2004	2002	2005	2009	2006	NA
9th yr Measure	2002	2003	2003	2003	2003	2003	2004	2004	2004	2005	2006	2006	2006
Prune Lift 3 18ft	NA	2011	2011?	2011?	NA	2006	2012	2010	2004	2011	2012	2011	NA
12th yr Measure	2005	2006	2006	2006	2006	2006	2007	2007	2007	2008	2009	2009	2009
30-32' HLC Thin	2007	?	2011?	2011?	?	2011?	2012?	2010	2012	2011?	?	?	?
Prune Lift 4 22 ft	NA	?	?	?	NA	2011?	2012?	2012	2007	2013?	?	?	NA
17th yr Measure	2010	2011	2011	2011	2011	2011	2012	2012	2012	2013	2014	2014	2014
22nd yr Measure	2015	2016	2016	2016	2016	2016	2017	2017	2017	2018	2019	2019	2019

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
24th yr Measurement	2013	2014	2015	2018

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	1993	1995	1995	1995	1996	1997	1998
2nd yr Regen Survey	1994	1996	1996	1996	1997	1998	1999
Plot Installation	1993	1996	1996	1996	1998	1999	2000
3rd yr Measurement	1995	1997	1997	1997	1998	1999	2000
6th yr Measurement	1998	2000	2000	2000	2001	2002	2003
9th yr Measurement	2001	2003	2003	2003	2004	2005	2006
12th yr Measurement	2004	2006	2006	2006	2007	2008	2009
17th yr Measurement	2009	2011	2011	2011	2012	2013	2014
22nd yr Measurement	2014	2016	2016	2016	2017	2018	2019

for the list of activities. Work includes:

- One Type 1 measurement:
  - Janicki (19th year measurement).
- Five Type 2 measurements/treatments:
  - John's River (3rd pruning lift)
  - Scappoose (3rd pruning lift and 3rd thin)
  - Blue Mtn. (17th year measurement)
  - Campbell River (17th year measurement, 4th pruning lift and 3rd thin)
  - Hemlock Creek (17th year measurement)
- No Type 3 measurements

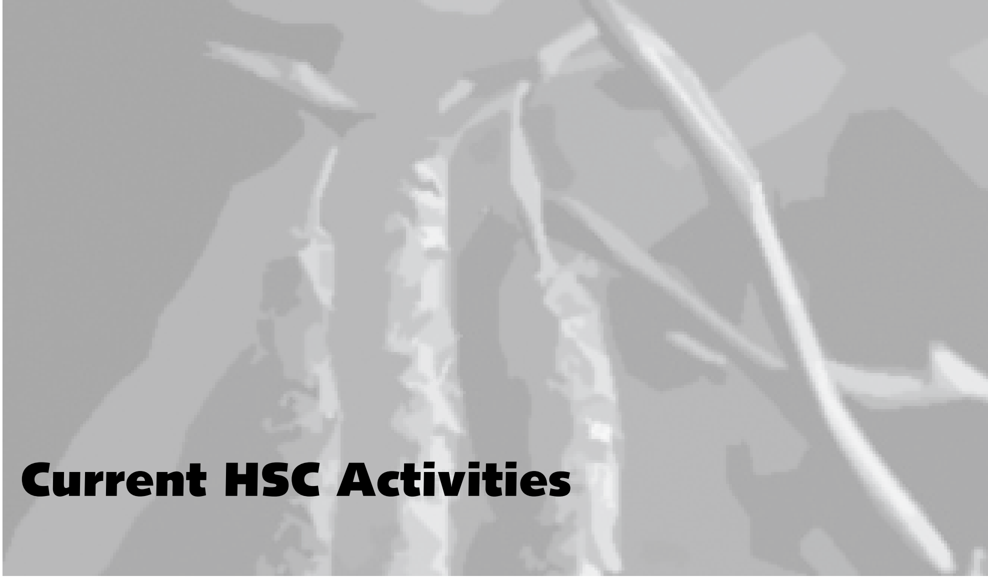
Of note, there are three "orphaned" installations to be measured/treated that may not have field crews available.

Table 5. Hardwood Silviculture Cooperative Field Activities, Winter 2008/09

Type	Activity	Installation	Cooperator
Type 1	19 yr measurement	2101	SNF- Battle Saddle
Type 2	12yr Measurement	3208	ODF- Weebe Packin
		3210	Orphaned- Wrongway Ck.
		5205	Orphaned- Tongue Mtn.
	15-20ft HLC Thin	3208	ODF- Weebe Packin
		3210	Orphaned- Wrongway Ck.
		5205	Orphaned- Tongue Mtn.
	2nd-3rd Pruning Lift	3204	SNF- Keller-Grass (3rd)
		3208	ODF- Weebe Packin (2nd)
	17yr Measurement	2203	FORCAP- Pioneer Mtn.
		3203	Orphaned- Sitkum
		3204	SNF- Keller-Grass
		3205	ODF- Shamu
		5203	BLM- Thompson Cat
	30ft HLC Thin	2203	FORCAP- Pioneer Mtn.
		5203	BLM- Thompson Cat
	4th Pruning Lift	2203	FORCAP- Pioneer Mtn.
		5203	BLM- Thompson Cat
Type 3	12yr Measurement	5301	Orphaned- Puget
	17yr Measurement	4302	MCMin- East Wilson

Table 6. Hardwood Silviculture Cooperative Field Activities, Winter 2009/10

Type	Activity	Installation	Cooperator
Type 1	19 yr measurement	4102	DNR- Janicki
Type 2	3rd Pruning Lift	2201	WHC- John's River
		3209	BLM- Scappoose
	17yr Measurement	3206	WHC- Blue Mtn.
			BCMIN- Campbell River
		5204	WHC- Hemlock Ck.
	30ft HLC Thin	4203	BCMIN- Campbell River
		3209	BLM- Scappoose
	4th Pruning Lift	2203	BCMIN- Campbell River (check HLC)
Type 3	None		



Current HSC Activities

ORGANON Growth and Yield Modeling

Background

The HSC is currently developing a new version of ORGANON for red alder plantations (RAP-ORGANON). This version of ORGANON will be the first red alder growth and yield model that will specifically model the behavior of plantations.

The majority of the funding from the project came from a wide range of agencies, both public and private. Further funding was received from the PNW Station's FY08-10 Agenda2020 fund.

Procedure

Data from the HSC red alder plantations (Type 2) and from other sources (mainly Weyerhaeuser Co.) was checked for errors and properly formatted. We then "explored" the data (i.e. looking at the ranges and patterns of the data, identifying relationships, looking for "weird" behavior, etc.) and tested to see if there was an effect of density on (height) growth, and if so, how to address it in the model.

We then calculated the following essential modeling variables: number of trees per acre (TPA) on each plot, basal area per acre (BA) of each plot, crown competition factor (CCF) for each plot, BA in larger diametered trees for each sample tree on each plot (BAL), CCF in larger diametered trees for each sample tree on each plot (CCFL), average height of the forty largest diametered trees per acre on each plot (H40), average DBH of the forty largest diametered trees per acre on each plot (D40), and percent crown closure at the top of each sample tree on each plot (CCH).

Dominant height growth equations were then developed (see below) to calculate site index (SI) of each plot and these values were added to the data sets.

These data sets were then used to develop the following equations: dominant height growth, maximum crown width, largest crown width, crown profile, height-diameter, and height-to-crown-base.

Results to Date

Dominant Height Growth

See below

Maximum Crown Width

Maximum crown width (MCW), defined as the greatest horizontal extension of the crown of open-grown trees, is a necessary variable in the ORGANON model since the estimates are used to compute crown closure of the stand at the tip of each tree (that variable is then used to predict the rate of height growth).

Development of plantation-grown red alder MCWs followed the procedures found in: Paine and Hann (1982) and Hann (1997).

MCW is usually predicted by simple linear regression using diameter at breast height (DBH) alone:

$MCW=a_0 + a_1DBH$

First, a check on the assumption that lcw=mcw for open-grown trees was performed. If this was true, then trees with a crown ratio=1.0 could be used in the MCW analysis (n=9848).

However, that assumption seemed incorrect so three constraints were placed on trees that could be used in the MCW calculation: 1) CR=1.0, 2) LCW/HT is between 0.7 and 1.0, and 3) (HT-4.5)/DBH is between 0.0 and 5.0. This reduced the number of suitable trees to 62.

All trees were less than 10 inches so to try to extend the curve, data from three very large red alder trees were used. Visual assessment showed that these three trees seemed to line up surprisingly well (Figure 2). Measurement attributes for the MCW modeling dataset are found in Table 7.

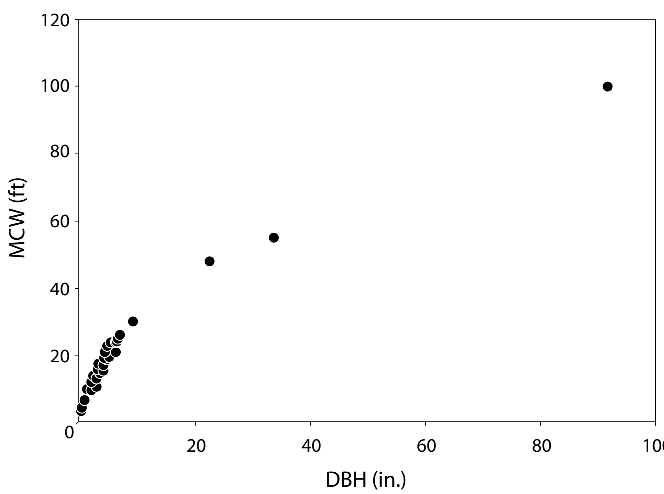


Figure 2. Relationship between maximum crown width (MCW) and diameter at breast height (DBH) for trees used in the maximum crown width analysis.

Table 7. Measurement attributes for the modeling dataset used for the maximum crown width analysis.

Attribute	Mean	Minimum	Maximum
Modeling Dataset (n = 65)			
DBH (in)	6.06	0.12	91.70
Height (ft)	25.84	4.63	134.00
MCW (ft)	19.42	3.54	100.00

The data was then fit with a non-linear equation of the following form: $MCW = a_0 + a_1*DBH^{0.6}$.

Largest Crown Width

An equation to predict the largest crown width (LCW) of a given tree within a stand can be combined with a crown profile equation to predict crown width (and thus CCF) at any point in the crown.

LCW modeling followed the procedures of Hann (1997). Due to differences in the definition of height to crown base between the HSC and the Weyerhaeuser (WeyCo) datasets, the equation was fit using WeyCo plantation data for red alder (33,980 observations). Measurement attributes for the LCW modeling dataset are found in Table 8.

Table 8. Measurement attributes for the modeling dataset used for the largest crown width analysis.

Attribute	Mean	Minimum	Maximum
	Control Plot Dataset (n = 33980)		
DBH (in)	2.90	0.20	10.30
Height (ft)	25.54	4.60	67.60
Crown length (ft)	19.71	2.00	51.50
Largest Crown Width (ft)	10.29	1.00	30.00
Maximum Crown Width (ft)	12.43	8.30	23.80

The model form used to fit the data was:

$LCW = a_0 \times MCW \times CR^{a1}$

Crown Profile

In ORGANON, crown closure of the stand at various heights affect individual tree height growth and mortality. The crown profile equation is used to calculate: 1) Crown closure of the plot at the tip of the subject tree (CCH). The height (H) of the subject tree is used to define a reference height (RH). Crown width (CW) at this RH for all other trees on the plot were estimated using the largest crown width (LCW) equation. CW for each tree is then converted to crown area (CA). The CAs were summed across all trees and expressed as a percentage of acreage covered and 2) crown competition factor (CCF) and CCF in trees with DBH greater than that of the subject tree (CCFL) were calculated. CCF is a measure of stand density that is independent of site quality and stand age.

The crown profile dataset consisted of measurements taken by the HSC on 47 trees from four sites and by the BC Ministry of Forests on 29 trees from three sites. Measurement attributes for the crown profile dataset are found in Table 9.

Table 9. Measurement attributes for the crown profile dataset.

Attribute	Mean	Minimum	Maximum
	Crown Profile Dataset (n = 76)		
DBH (in)	7.22	0.70	18.10
Height (ft)	51.58	13.10	124.00
HLC (ft)	23.68	0.16	93.30
DBH/HT	0.14	0.05	0.24
Branch radii (ft, n=422)	8.05	0.40	30.30

The datasets were combined and individual tree profiles were plotted to 1) identify potentially suspect measurements, and 2) to assess where the distance from crown base (DACB) to where LCW occurred. DACB is the splining point of the two crown profile equations. Preliminary analysis showed that as the trees got taller the DACB/crown length (CL) got higher in the tree. Figure 3 illustrates typical crown profiles for "short" (a) and "tall" (b) red alder.

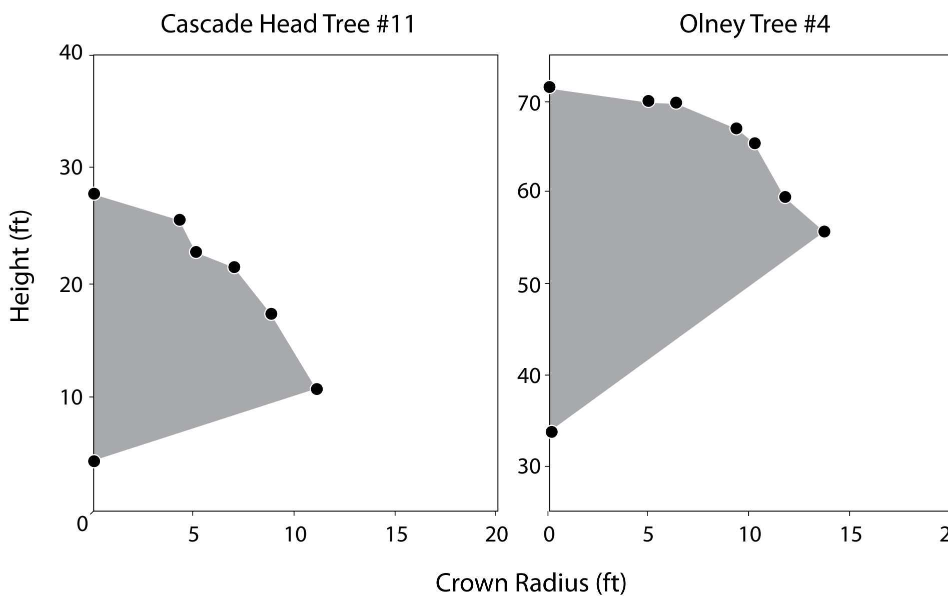


Figure 3. Comparison of typical red alder crown profiles for a "short" tree (a) and a "tall" tree (b). Note different y-axis scale.

Datasets were then developed to model the three components of crown profile: the crown width above LCW, the crown width below LCW, and the distance above crown base where LCW occurs. Measurement attributes for these datasets are found in Table 10.

Crown profile was predicted by the equations developed by Hann (1999).

Table 10. Measurement attributes for the modeling dataset used for the crown profile analysis. CWA is the crown width above HLCW at a height of h feet from the ground, CWB is the crown width below HLCW at a height of h feet from the ground, HLCW is the height from the ground where LCW occurs, and DACB is the distance above HCB to HLCW.

Attribute	Mean	Minimum	Maximum
CWA and CWB Dataset (n = 362)			
Height (ft)	51.79	13.10	124.00
DBH (in)	7.20	0.70	18.10
HT/DBH	7.59	4.11	18.71
DACB Dataset (n=76)			
DACB (ft)	12.61	0.16	38.89
Height (ft	51.02	13.10	124.00
Crown Length (ft)	26.0 4	5.76	49.65

$$CWA_h = LCW \bullet RPA_h^{[b_0 + b_1 RPA_h^{1/2} + b_2 (HT/DBH)]}$$

$$RPA_h = \frac{HT - h}{HT - HLCW}$$

$$HLCW = HCB + DACB$$

$$DACB = b_3 CL \bullet e^{[b_4 (1.0 - \frac{HT}{140})^3]}$$

$$CWB_h = LCW \bullet [RPB_h + b_5 (1.0 - RPB_h)]$$

$$RPB_h = \frac{h - HCB}{DACB}$$

Where,

CWA_h = Crown width above *HLCW* at a height of h feet from the ground
HLCW = Height from ground where *LCW* occurs
LCW = Largest crown width of the tree
RPA_h = Relative position above *HLCW* where CWA_h is to be predicted
CWB_h = Crown width below *HLCW* at a height of h feet from the ground
RPB_h = Relative position below *HLCW* where CWB_h is to be predicted
DACB = Distance above *HCB* to *HLCW*
HT = Total tree height
DBH = Diameter at breast height
HCB = Height to crown base
CL = Crown length (*HT* – *HCB*)

Height-Diameter Relationship

Tree height is a critical variable for modeling tree and stand growth, however measuring tree heights are time consuming. Therefore, tree heights are usually sub-sampled and the remaining heights are estimated with height-diameter equations.

There have been many studies of height-diameter relationships and thus many equation forms. Two model forms were used here. The first was presented by Curtis (1967) where:

$HT = 4.5 + \exp(b_0 + b_1 * DBH^{b2})$

The second was presented by Krumland and Wensel (1988) where:

$HT = (b_0 + (H40-4.5) * EXP(b_1 * (DBH^{XX} - D40^{XX})))$

$XX = b_1 + b_2 * (H40-4.5)$

H40= Height of the 40 largest-diameter trees/acre

D40= Diameter of the 40 largest-diameter trees/acre

The height-diameter modeling procedure followed that of Hanus, et.al. (1999).

The above two equations were transformed using sqrt(DBH) and fit to two datasets; all trees (n=149823) and undamaged trees (n=148683). Measurement attributes for the height-diameter modeling dataset (all trees) are found in Table 11. The relationship between diameter and height for all trees is shown in Figure 4.

The Krumland and Wensel model form fit the data better and was therefore used to fill in missing heights. Finally, to improve predictions, this "regional equation" was calibrated to the measurements of height on each plot-measurement combination. This "calibrated equation" was then used to fill in each plot-measurement's missing heights.

Table 11. Measurement attributes for the modeling dataset used for the height-diameter analysis.

Attribute	Mean	Minimum	Maximum
	Modeling Dataset (n = 149823)		
DBH (in)	2.63	0.20	14.10
Height (ft)	23.77	4.60	83.30
D40 (in)	3.52	0.30	12.30
H40 (ft)	27.38	6.50	80.80

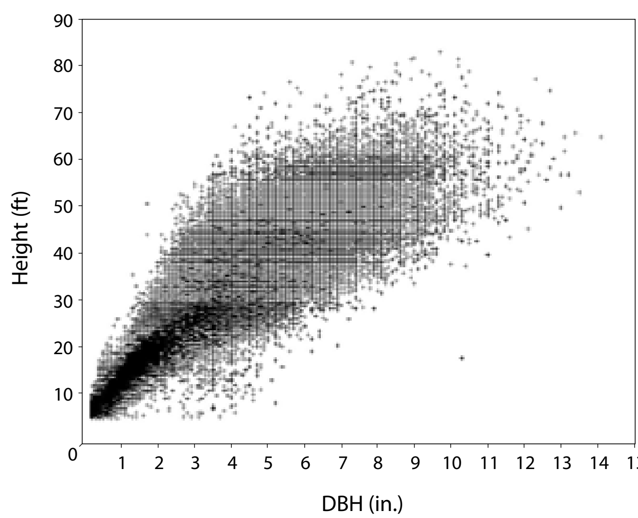


Figure 4. Relationship between diameter (DBH) and height (HT) for trees used in the height-diameter analysis.

Height-to-Crown-Base

Since live crown length or relative crown length (crown ratio) is a proxy for the quantity of foliage on a given tree, it is often a predictor variable in growth, mortality, volume, and taper equations.

In this effort the equation for predicting height to crown base (HCB) and bole ratio (BR=HCB/HT) followed the form presented in Ritchie and Hann (1987):

$$BR = \{1 + EXP[a_0 + a_1 \cdot Ht/100 + a_2 \cdot CCFL/100 + a_3 \cdot \ln(BA) + a_4 \cdot \ln(DBH/Ht) + a_4(SI\text{-}4.5)/100]\}^{-1}$$

Where,

BR =Bole Ratio, HCB/Ht

HT = Total Tree Height in Feet

CCFL = Crown Competition Factor in Trees with Larger DBH in Percent

BA = Stand Basal Area per Acre

DBH = Diameter at Breast Height in Inches

SI = Weiskittel et al. (2009) Site Index in Feet

The objective of this analysis was to develop two equations for predicting (HBC). The first equation was developed with a data set that included all trees and will be used to predict missing measurements of HCB. The second equation was developed with a data set that included only undamaged trees and will be used to predict crown recession.

The fitting process was extensive and required fitting many alternative model forms. Probable causes of the discrepancies include differences in the definition of HCB between datasets, differences in the definition of damaged trees, and/or differences in field assessments of trees with CR=1.0.

Because these differences could not be adequately addressed, two HCB equations were developed, one for each of the control plot datasets (one for WeyCo [n=40415] and the other for HSC [n=26020]). Combined measurement attributes for the two control plot height-to-crown-base datasets are found in Table 12.

Table 12. Measurement attributes for the height-to- crown-base control plot (modeling) dataset and the untreated plot (validation) dataset plots used in dominant height growth analysis.

Attribute	Mean	Minimum	Maximum
	Control Plot Dataset (n = 66435)		
DBH (in)	2.92	0.20	14.10
Height (ft	25.79	4.60	83.30
HCB (ft)	7.87	0.00	62.70
Basal area (ft^2 ac^{-1})	34.26	0.05	134.66
CCFL	127.61	0.00	715.13
Site Index (ft)	63.87	32.20	90.50
	Untreated Plot Dataset (n=80899)		
DBH (in)	2.43	0.20	10.80
Height (ft	22.40	4.60	77.80
HCB (ft)	5.77	0.00	45.90
Basal area (ft2 ac-1)	21.48	0.26	117.61
CCFL	96.67	0.00	496.88
Site Index (ft)	58.61	22.70	87.90

This model form constrains BR towards zero as BA approaches zero. However, that constraint was not reasonable for these datasets. For BA values of 2 square feet per acre or less, the average HCB was 2.0 feet for the HSC data set and it was 0.8 feet for the WeyCo data set.

The following revised model form was therefore developed to incorporate the fact that BR (HCB) do not go to zero as BA approaches zero:

$$RBR = \{1 + EXP[a_0 + a_1 \cdot Ht/100 + a_2 \cdot CCFL/100 + a_3 \cdot \ln(BA) + a_4 \cdot \ln(DBH/Ht) + a_4(SI\text{-}4.5)/100]\}^{-1}$$

Where,

RBR = Revised Bole Ratio, (HCB-K)/(Ht-K)

The resulting equation for predicting HCB is:

$$HCB = \{Ht - K\}\{1 + EXP[a_0 + a_1 \cdot Ht/100 + a_2 \cdot CCFL/100 + a_3 \cdot \ln(BA) + a_4 \cdot \ln(DBH/Ht) + a_4(SI\text{-}4.5)/100]\}^{-1} + K$$

and where,

k = 2.0 for the HSC dataset and k=0.8 for the WeyCo dataset

These two final equations (all trees and undamaged trees) were then validated using data sets from untreated plots (WeyCo [n=49086]and HSC [n=31813]).

The HSC model seemed to validate well for both data sets, while the WeyCo model did not validate as well. In either case, the control and validation data sets were then combined to calculate “final” equation parameters.

Future Work

We are currently working on developing the remaining equations for control/untreated stands; diameter growth rate, height growth rate, mortality rate, crown recession, and size-density relationship. Once this work is completed, we will work on thinning responses. The estimated completion date is by the end of 2009 but is contingent on acquiring additional funds.

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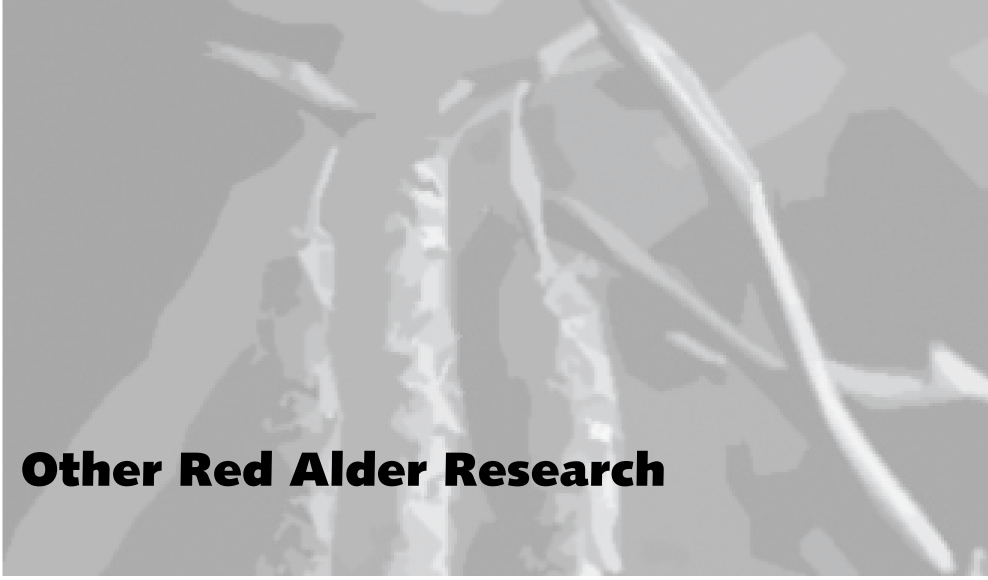


Other Red Alder Research

Modeling Top Height Growth of Red Alder Plantations. 2009.

Weiskittel, A.R.[a], D.W. Hann[b], D.E. Hibbs[c], T.Y. Lam[b], and A.A. Bluhm[c]. Forest Ecology and Management. 258:323-331.

[a] School of Forest Resources, University of Maine

[b] Department of Forest Engineering, Resources, and Management, Oregon State University

[c] Department of Forest Ecosystems and Society, Oregon State University

The following is a copy of the abstract and a summary of some pertinent results.

Abstract

Height growth equations for dominant trees are needed for growth and yield projections, to determine appropriate silvicultural regimes, and to estimate site index. Red alder [*Alnus rubra* Bong.] is a fast-growing hardwood species that is widely planted in the Pacific Northwest, USA. However, red alder dominant height growth equations used currently have been determined using stem analysis trees from natural stands rather than repeated measurements of stand-level top height from plantations, which may cause them to be biased. A regional dataset of red alder plantations was complied and used to construct a dynamic base-age invariant top height growth equation. Ten anamorphic and polymorphic Generalized Algebraic Difference Approach (GADA) forms were fit using the forward difference approach. The Chapman-Richards anamorphic and Schumacher anamorphic model forms were the only ones with statistically significant parameters that yielded biologically reasonable predictions across a full range of the available data. The Schumacher model form performed better on three independent datasets and, therefore, was selected as the final model. The resulting top height growth equations differed appreciably from tree-level dominant height growth equations developed using data from natural stands, particularly at the younger ages and on lower site indices. Both the rate and shape parameters of the Schumacher function were not influenced by initial planting density. However, this analysis indicates that the asymptote, which is

related to site index, may be reduced for plantations with initial planting density below 500 trees ha^{-1}. The final equation can be used for predictions of top height (and thus) site index for red alder plantations across a range of different growing conditions.

Introduction

Several tree-level dominant height growth equations exist for natural, unmanaged red alder stands. However, a tree-level dominant height growth or a stand-level top height growth equation for managed red alder plantations does not exist and is much needed in the region.

In addition, all existing dominant height growth equations for red alder were developed using tree-level stem analysis data as opposed to repeated measurements of stand top height, which can significantly influence the behavior of the site curves.

A key assumption in using dominant height or top height as an index of site productivity potential is that height growth of dominant trees is not influenced by stand density. Several studies have shown this to be generally the case. However, stand density has been found to affect dominant height growth for a number of predominantly intolerant species. As a result, stand density has been incorporated into dominant height growth equations for some species

Objectives

The overall goal of this research project was to model top height growth of plantation grown red alder.

Specific objectives were to: (1) fit several different height growth model forms using alternative statistical techniques; (2) compare the predictive performance of the resulting equations on both the modeling data set and an independent validation data set; (3) for the final model, compare predicted development of top height in plantations to the development of dominant height in natural stands, and (4) for the final model, assess the influence of planting density on estimated top height growth.

Table 13. Measurement attributes for the modeling (n = 797) and validation (n = 790) plots used in dominant height growth analysis.

Attribute	Mean	Standard Deviation	Minimum	Maximum
Modeling plot/measurements (n = 797)				
Top Height (m)	10.9	4.6	1.9	24.6
Total Age (years)	8.9	4.0	3.0	18.0
Planting Density (# ha^{-1})	1346.7	889.7	168.0	3765.8
Trees per ha	1278.1	826.2	138.4	3743.6
Basal area (m^2 ha^{-1})	10.1	8.2	0.1	30.9
Validation plot/measurements (n = 790)				
Top Height (m)	9.7	4.0	2.1	20.4
Total Age (years)	7.5	3.4	3.0	17.0
Planting Density (# ha^{-1})	1719.7	813.6	370.6	3654.6
Trees per ha	1200.1	744.5	252.0	3617.5
Basal area (m2 ha-1)	6.2	5.4	0.1	27.0

Data

Modeling data came from sixty existing research installations of the HSC and WeyCo (Table 13).

Validation data came from two other HSC datasets, one with very young trees (153 total plots; ages of one, two, and three years old) and one with older trees of natural origin (four plots; ages 29 to 32-years old).

Results

Only two model forms had statistically significant parameters and expected behavior. These were the Chapman-Richards and the Schumacher anamorphic model forms.

The anamorphic model forms performed better than the polymorphic model forms. This finding is consistent with existing tree-level dominant height growth curves for red alder.

Graphs of predicted top height (HD_P) over age for four SI values (40, 60, 80, and 100 ft at 20 years) for the two models are seen in Figure 5.

Graphs of HD_P periodic annual increment (PAI) for the two models are presented in Figure 6. The Schumacher model had higher peak PAI values than the Chapman-Richards model and also predicted higher PAI values for ages above 18 years.

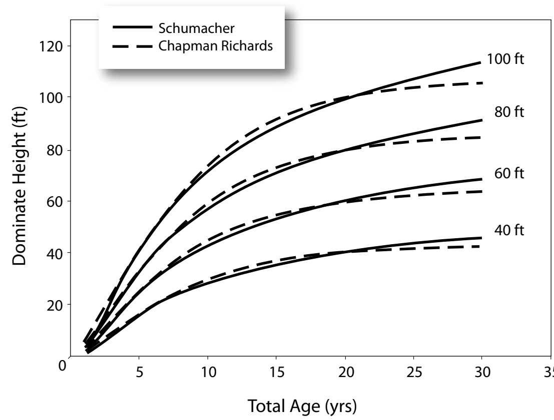


Figure 5. Comparison of predicted dominant height from the Schumacher and Chapman-Richards dominant height growth model forms.

Figure 6. Comparison of predicted periodic annual increment (PAI) height from the Schumacher and Chapman-Richards dominant height growth model forms.

Examination of the results across the measurement ages showed that the Schumacher equation was more accurate and its precision was greater than the Chapman-Richards equation and was therefore the best model for predicting HD_M in red alder plantations.

For comparative purposes, predictions from the natural stand, tree-level dominant height growth equation of Harrington and Curtis (1986. Height growth and site index curves for red alder. USDA For. Serv. Res. Paper PNW-358) are shown along with the Schumacher model. The Schumacher model form produced appreciably (and statistically significant) different growth curves than the Harrington and Curtis model (Figure 7).

When the Harrington and Curtis equation was applied to the modeling data, a bias was observed throughout the range of the data. This indicated that the dominant height growth of trees in natural red alder stands differ significantly from the top height growth of trees in plantations.

A graph of the residuals over planting density illustrated slight under-prediction for stands with a planting density less than 500 trees ha^{-1} and a slight over-prediction for stands with a planting density greater than 1500 trees ha^{-1} (Figure 8).

Furthermore, a graph of relative site index (SI) over planting density (Figure 9) showed a trend indicating that the predicted SI for plots with planting densities under 500 trees ha^{-1} were always lower than the largest SI value for a given installation and that the size of the difference increased as the planting density decreased. However, statistical tests indicated that planting density did not significantly affect the rate and shape parameters of the model.

The implication of this is that the impact of low planting density on HD_P is the same thing as lowering the SI estimate for the plot of interest. Another implication of this finding is that predicted SI for stands below a planting density of 500 trees ha^{-1} would require some type of correction if SI is to be used as a measure of site productivity in red alder plantations.

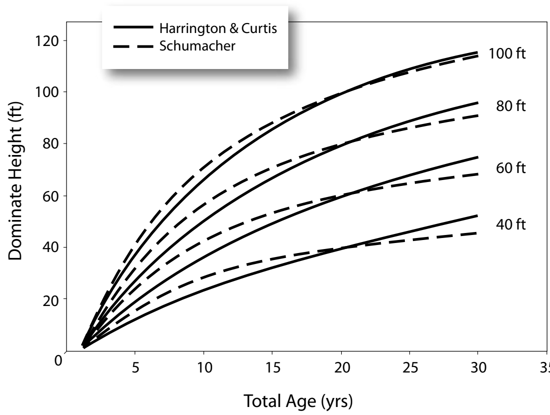


Figure 7. Comparison of predicted dominant height from the Schumacher and Harrington and Curtis dominant height growth model forms.

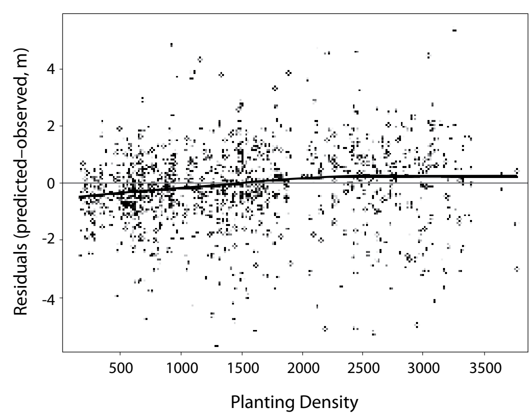


Figure 8. Plot of residuals (HD_P minus HD_M) from the Schumacher anamorphic equation fit over initial plant density (trees ha^{-1}).

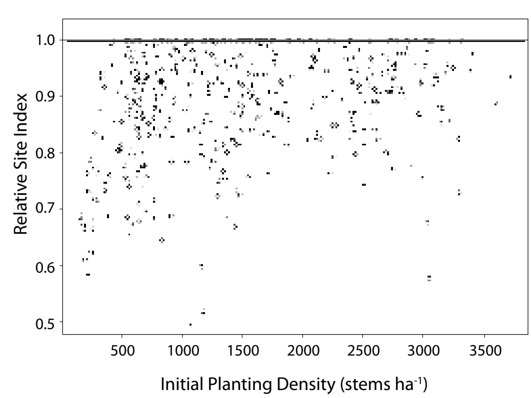


Figure 9. Plot of relative Schumacher site index over planting density for the modeling and validation data sets combined

The Effect of Stand Density on Height and Diameter Growth of Planted Red Alder.

Lam, T.[a], *and Bluhm, A.*[b]

[a] Department of Forest Engineering, Resources, and Management, Oregon State University

[b] Department of Forest Ecosystems and Society, Oregon State University

The following is a description of the proposed research.

Introductionn

Traditionally, the two primary assumptions about tree growth in relation stand density are: (1) diameter (DBH) growth is inverse of stand density, and (2) height growth is independent of stand density. However, preliminary analyses suggest that these assumptions might not hold for selected subsamples of planted red alder. There are several management implications if these two assumptions do not hold: (1) the standard measures of site productivity (e.g. site index) – which assume independence of height growth and stand density – may need revision, and (2) density management decisions that primarily focus on DBH growth would need to consider height growth (and a possible height and DBH growth interaction) as well.

Experimental Design

The data used in this analysis are from the HSC Type 2 installations. The experimental design is a Randomized Complete Block with a Split-Plot Design consisting of 26 variable-density plantations (blocks) of pure stands of red alder in Western Oregon, Western Washington and Southwestern British Columbia (see Figure 1). Within each block, there are four whole-plot experimental units each with a general target planting density (247, 570, 1300, 3000 trees/ha). Each whole-plot experimental unit is further subdivided into several sub-plots where control, thinning and pruning treatments were applied. Each sub-plot is 0.50 ha in size and contain a 0.13 ha measurement plot with 20-m buffers. Seedling survival was evaluated at year one and year two and if mortality exceeded 30 percent during this time the plots were interplanted. All invading trees (i.e. ingrowth) and overtopping woody shrubs were controlled.

Data was collected from the measurement plots at when the plantation was 3, 6, 9, 12 and 17 years old (add one year for total tree age). For every tree, DBH (defined at 1.37m), stem defect (fork, lean, sweep) and presence or absence of damage (animal, weather, etc) was recorded. Height was measured on a subsample of 40 trees spatially well distributed over the plot that included 10 trees of the smallest DBH, 10 trees of the largest DBH, and 20 mid-range trees (based on DBH). Missing heights will be calculated from the height-diameter relationship developed for the RAP-ORGANON project (see above).

Hypotheses (null)

H1: Stand density does not have an effect on height growth,

H2: Stand density does not have an effect on DBH growth,

H3: Stand density does not have an effect on both height and dbh growth (i.e. volume),

H4: For each of the above hypotheses, different subsamples of the population do not affect the outcomes of hypothesis testing.

Response Variables

Only the control treatment sub-plots will be analyzed. Thus, the response variables will be calculated as experimental unit-level average. The response variables are:

- Total Height,
- DBH,
- Whole Tree Volume,
- Height Growth,
- DBH Growth,
- Volume Growth

Population Subsamples

To allow the testing of H4, four distinct subsamples of the trees found in each experimental unit will be selected and the six response variables will be calculated for each population subsample:

- ALL – All trees (including stem defect and presence of damages),
- L247 – the 247 biggest trees/ha (based on DBH).
- L100 – the 100 biggest trees/ha (based on DBH).
- S100 – the 100 smallest trees/ha (based on DBH).

Analytical Approaches

Several analytical approaches are being considered for this project. Depending on the structure and characteristics of the data, one (or a combination of) the following approaches will be used:

Repeated Measures ANOVA,
Nonlinear regression with random effect,
Nonlinear regression with random effect and hierarchical structure.

Ectomycorrhizal Assemblages in *Alnus rubra* Forests: Low Species Richness, High Genus-level Host Specificity, and Strong Host Age Effects. *In review*. Plant and Soil.

Kennedy, P., and Hill, L.

Department of Biology, Lewis and Clark College

The following is a copy of the abstract and a summary of some preliminary results.

Abstract

The nitrogen fixing symbiosis between *Frankia* bacteria and *Alnus* plants is widely recognized for its ecological importance, but the factors controlling *Frankia* diversity in *Alnus* forests are not well resolved. To quantify the diversity of *Frankia* associated with red alder (*Alnus rubra*) in natural settings, and to examine the relative importance of geographic location and host age in structuring *Frankia* diversity in red alder forests, we sampled root nodules from four red alder sites in the Pacific Northwest, USA. We compared *Frankia* genetic diversity at each site.

We encountered a total of 25 *Frankia* genotypes across all sites. Sites varied considerably in genotype composition and the total number of genotypes present. Phylogenetic analyses indicated that red alder associated *Frankia* fall into two main *Frankia* groups; the *Alnus*-infective cluster and, less frequently, the *Elaeagnus*-infective cluster. Analyses revealed that *Frankia* assemblages were structured significantly by geographic location (east vs. west side of the coast range mountains) but not by host age. Our study indicates that the *Frankia* assemblages on red alder are genetically diverse and geographically structured, which may both have important effects on host-symbiont interactions.

Objectives

Three questions were addressed: 1) How many *Frankia* genotypes are associated with red alder in natural settings, 2) How are red alder associated *Frankia* phylogenetically related to one another as well as other *Frankia*, and 3) How are *Frankia* assemblages influenced by geographic location and forest age? To answer these questions, we sampled four red alder stands varying in age and geographic location and compared the *Frankia* genetic diversity.

Study Sites

Four sites in Western Oregon were chosen. Two of the sites are HSC Type 2 installations- Toledo (#2203) and Thompson Cat (#5203). Both were established in 1992, with the former located in the Coast Range and the latter located in the Cascade Range. Seedlings were planted from nursery stock and *Frankia* nodule status at the time of planting was not assessed. However, nursery fumigation practices indicate nodulation was very unlikely. The third site, Fox Creek, was located in the Coast Range and the fourth site, Mt. Hood, was located in the Cascade Range. Both sites were an unmanaged, naturally regenerating mature red alder stand approximately 60-70 years in age. Additional details about each site are listed in Table 14.

Table 14. Origin, region, age, soil and climate information for the four study sites used in this study.

Site	Origin	Region	Stand Age (yr)	Soil Series	Altitude (m)	Mean Precip (mm/yr)
Thompson Cat	Planted	Cascade Range	16	Aschoff cobbly loam	391	1983
Mount Hood	Natural	Cascade Range	~60	Not available	556	1973
Toledo	Planted	Coast range	16	Tolovana-Reedsport complex	38	2312
Fox Creek	Natural	Coast range	~70	Alic-Hapludands complex	154	2138

Results

Twenty-five different *Frankia* types (hereafter referred to as genotypes) were detected.

Of the 25 genotypes encountered, only one was present at all four sites while 11 were unique to single sites. Although richness was not equally distributed among sites, there was no clear pattern in richness associated with host age or geographic location.

Across sites, the number of individuals per genotype ranged from 112 to 1, with a median of 14 individuals per genotype. All sites were dominated by only one or two genotypes, but varied considerably in the total number present.

The composition of genotypes between plots within sites was consistently more similar than the composition among plots across sites (Figure 10a) despite considerable differences in tree density within sites. There was a significant difference in assemblage structure: the Toledo and Fox Creek sites, in the Coast Range, were more similar in structure to each other than the sites in the Cascade Range (Figure 10b). The geographic pattern observed did not appear to reflect a limitation to dispersal, since multiple genotypes found at Toledo and Fox Creek were also encountered at one of the two Coast Range sites as well. Instead, it appeared that individual genotypes may have preferences for different environmental conditions present on the two mountain ranges (previous studies have found that *Frankia* composition and abundance can vary along temperature/moisture/elevation gradients).

When sites were grouped by age (i.e. younger vs. older), however, there was no significant difference in assemblage structure.

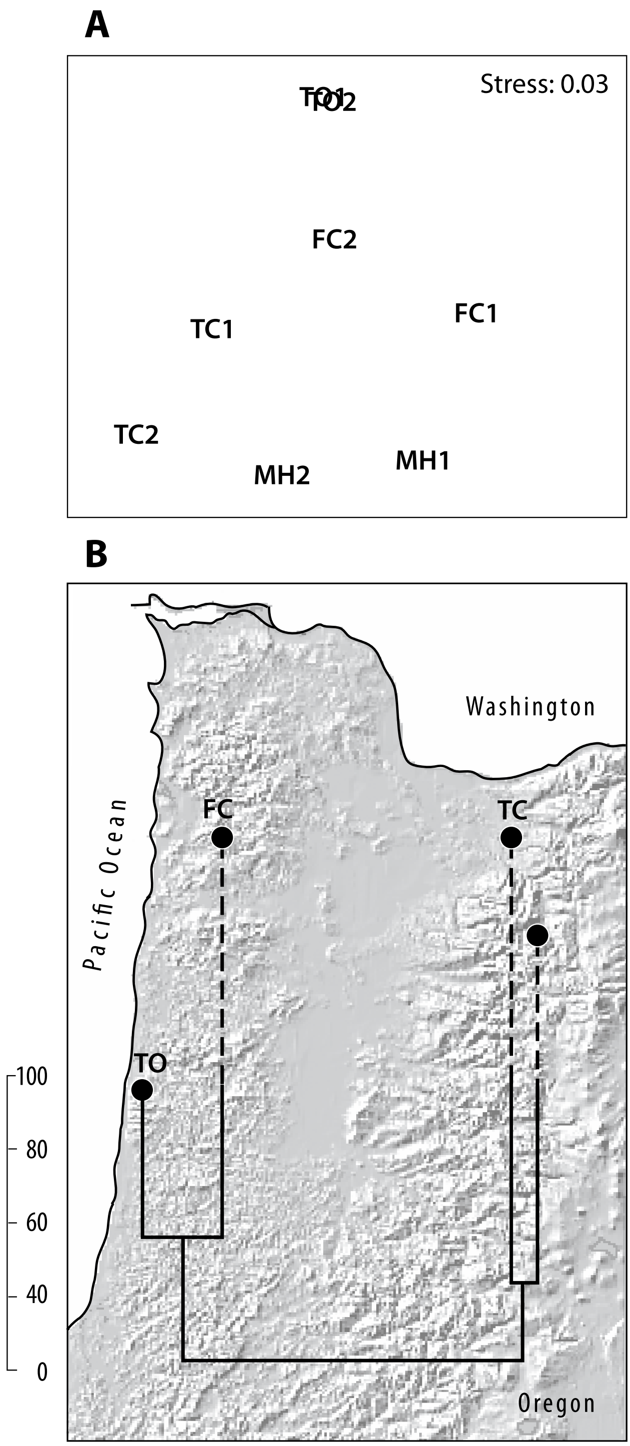


Figure 10. Non-metric multidimensional scaling diagram of the plots at each of the four sites (a) and hierarchical clustering diagram (b) showing the % similarity based on genotype composition and abundance among sites. Site abbreviations are TC – Thompson Cat, TO – Toledo, MH – Mount Hood, and FC – Fox Creek.

Using Red Alder as an Adaptation Strategy to Reduce Environmental, Social and Economic Risks of Climate Change in Coastal BC.

de Montigny, L. et al.

British Columbia Ministry of Forests and Range, Research Branch

The following is an abridged version of the research proposal.

Background

Red alder is the most common broadleaf tree in the Pacific Northwest with a range stretching from coastal southeast Alaska to southern California. Inventory estimates for red alder in B.C. are 91.9 million m^3 for all stand types and 29.7 million m^3 for alder- leading stands. Red alder is expected to increase in frequency and expand its distribution in B.C. in response to climate change

In pure stands on good sites, it has been estimated that red alder can achieve mean annual cubic volume growth rates of 21 m^3/ha in pulpwood rotations of 10 to 12 years, and 14 m^3/ha in sawlog rotations of about 30 years. Pure red alder plantations therefore can provide a range of forest products (from biofuels to sawlogs) but red alder has other beneficial effects- most importantly, its ability to increase soil nitrogen (N) availability due to symbiotic fixation of atmospheric N. Red alder has been shown to contribute to long-term site productivity, mitigate the effects of root disease and contribute to diversity, health and resilience of forests at both the stand and landscape levels.

In mixed stands with Douglas-fir, red alder's rapid juvenile height growth can reduce growth of Douglas-fir as a result of shading. However, this reduction in Douglas-fir growth may be offset by the increased N availability (low densities of red alder have been found to increase conifer growth). Red alder management in mixed stands requires balancing the negative effects of shading with its positive effects on nutrients. To do this successfully, a better understanding of the effects of red alder densities on mixed stand development and the influence of site factors on these interactions is required.

Because the range of red alder is expected to increase with climate change, and it is a short rotation high value crop providing a diversity of wood products, and improving long-term site productivity and ecosystem resiliency, leads us to the conclusion that increased use of red alder is an adaptation strategy that could reduce environmental, social and economic risks of climate change in coastal B.C. In addition, alder stands can be established to 'buy time' before having to make long term decisions on correct genetic material for conifer plantations.

Study Design

This proposed study has three components: biological, ecological and socioeconomic.

Biologic

For the biological component, we will use, in collaboration with the Hardwood Silviculture Cooperative, a large network of pure and mixed alder long-term research installations located from Vancouver Island to Oregon. The 26 HSC pure alder installations (Type 2 experiments) consist of blocks planted at 4 densities ranging from 250 to 3000 tph over which different silvicultural treatments were applied. The mixed species installations test the competitive effects of red alder on conifers and include 7 replacement series installations (HSC Type 3 experiments) and 4 additive series installations. The replacement series consist of red alder and Douglas-fir planted in 5 proportions: 1:0, 0.5:0.5, 0.25:0.75, 0.11:0.89 and 0:1 at a total density of 742 tph. The additive series consist of Douglas-fir and western redcedar planted in a 50:50 mix at a density of 1100 tph. One of five red alder densities (0 – 400 sph) were then systematically interplanted between the conifers.

Geographic information for the HSC Type 2 and Type 3 and the additive experiment installations will be input into the ClimatePNW model to provide climatic information. Effects of climate (GDD, MAT, MAP, growing season precipitation, monthly precipitation, minimum temperature, etc) on the growth of red alder and Douglas-fir will be examined. We will use regression analysis (non-linear mixed models and other appropriate methods) to examine effects of climate, site, and alder density on conifer growth.

We will use data from 2 alder provenance-progeny test trials (~40 provenances) located in southern and northern coastal B.C. To explore alder's ability to acclimate vs. adapt to variation in climate we will use data from alder progeny trials planted in contrasting climates. Genotype and environmental variability in growth, water use efficiency, cold hardiness and N2 fixation will be quantified in existing progeny trials in BC.

The biological component of this project also includes collection of soils data to complement the growth data by accurately characterizing the installations. From each installation of the additive and replacement experiments, soil drainage and moisture regimes will be characterized, soil samples analyzed for pH, total N, total C, available P, CEC and mineralizable N and Douglas-fir foliage analyzed for nutrient content. At selected sites we will examine rates of nitrogen fixation. This information is needed to effectively examine influences of climate, site factors, and alder density on nutrient availability. This will provide valuable information on potential effects of climate change on N fixation by red alder. The measurements of soil C at this time will provide a 15 year measurement that, combined with existing data taken at the time of establishment, will provide a significant contribution to the understanding of C sequestration in mixed species stands over that time period.

Potential implications of climate change on the growth of these two tree species alone and in mixture will be examined. Results will help to determine on what sites alder is beneficial to conifers, what factors may be responsible for the shifts in importance of competition relative to facilitation in these mixtures, and the potential effects of climate change. Understanding the confounding effects of climate, site, and density of alder is critical as studies suggest red alder may become more competitive to conifers on moist sites as climate changes.

Ecologic

The ecological component of the study will explore the expected migration of alder to sites that are currently too cold for alder growth. Alder is limited in elevation by snow break and by spring and fall frosts but is tolerant of wet soil conditions. Predicted increases in temperature and precipitation in coastal areas will likely increase its range. We will attempt to determine climatic suitability and limitations for productivity of red alder.

Socioeconomic

The socioeconomic study consists of 2 parts. On the social side, we will learn from the traditional knowledge of First Nations (i.e. Native American) elders. Alder has been an important wood for First Nations for thousands of years. First Nation oral stories can be used to document not only historical use, but also biological and growth characteristics during much earlier times (thousands of years) when the climate was different than today. From an economic perspective, we will determine what steps need to be taken to develop an integrated hardwood forest sector value chain industry. Red alder log and lumber prices have demonstrated stable upward growth for the last several decades. Soil expectation value (SEV) calculations have shown that with a price advantage and shorter rotation length, alder plantations may provide better return on investment than Douglas-fir plantations. In addition, jobs can be created for intensive management of alder plantations. An examination of the available information about alder product markets will provide a better understanding of the future potential performance of alder and the benefits to forest-dependent communities.

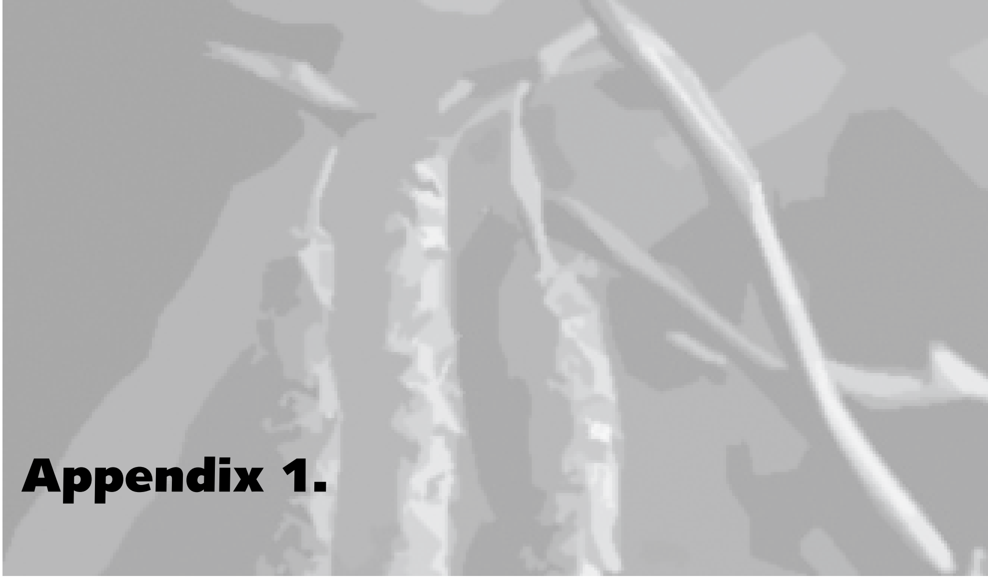
Conclusion

The synthesis of biological, ecological and socioeconomic information generated by collaborators in this project will result in the blueprints for an adaptation strategy to reduce environmental, social and economic risks of climate change in coastal B.C.

Direction for 2010

As always, the specific goals for 2010 are both continuations of our long-term objectives and new projects:

- Continue HSC treatments, measurements and data tasks.
- Keep the HSC website updated and current.
- Continue efforts in outreach and education.
- Continue efforts to recruit new members.
- Continue working with and analyzing the HSC data. Specifically address the possible effect of density on tree growth using the Type 2 data.
- Continue ORGANON modeling efforts in the creation of both a plantation model and a natural-stand model.



Appendix 1.

Summary of Red Alder Stand Management Study Treatments

Type I- Thinned Natural Red Alder Stands

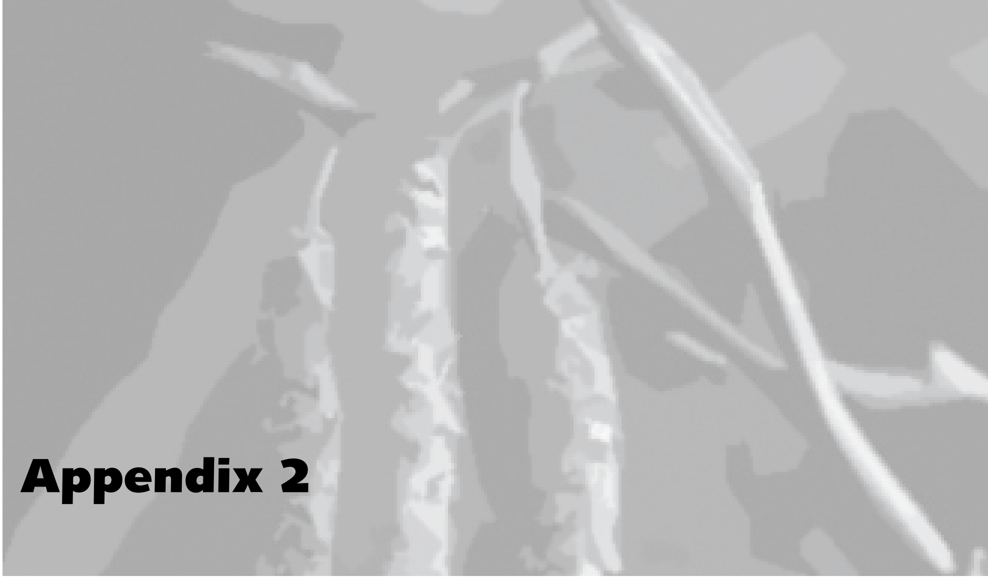
1. Control- measure only, stand left at existing density
2. 230 trees/acre (tpa) re-spacing density in year 3 to 5
3. 525 tpa re-spacing density in year 3 to 5
4. 230 tpa re-spacing density when height to live crown (HLC) is 15 to 20 feet
5. 525 tpa re-spacing density when HLC is 15 to 20 feet
6. Control- measure only, stand left at existing density
7. 100 tpa re-spacing density when HLC is 30 feet
8. 230 tpa re-spacing density when HLC is 30 feet
9. Control- measure only, stand left at existing density

Type 2- Red Alder Variable Density Plantations

1. 100 tpa control- measure only
2. 230 tpa control-measure only
3. 230 tpa pruned to 6 ft. lift, 12 ft lift, 18 ft lift, 24 ft lift
4. 525 tpa control -measure only
5. 525 tpa thin to 230 tpa in year 3 to 5
6. 525 tpa thin to 230 tpa when HLC is 15 to 20 feet
7. 525 tpa thin to 230 tpa when HLC is 30 to 32 feet
8. 1200 tpa control- measure only
9. 1200 tpa thin to 230 tpa in year 3 to 5
10. 1200 tpa thin to 230 tpa when HLC is 15 to 20 feet
12. 1200 tpa thin to 100 tpa when HLC is 15 to 20 feet
13. 525 tpa thin to 100 tpa when HLC is 15 to 20 feet

Type 3- Mixed Red Alder Douglas-fir Plantations

1. 100% red alder planted at 300 tpa density
2. 50% red alder and 50% Douglas-fir planted at 300 tpa density
3. 25% red alder and 75% Douglas-fir planted at 300 tpa density
4. 11% red alder and 89% Douglas-fir planted at 300 tpa density
5. 100% Douglas-fir planted at 300 tpa density



Appendix 2

HSC Management Committee Meeting Minutes

Summer Management Committee Meeting Minutes

Tuesday July 8, 2008:

Attendees: Andrew Bluhm, David Hibbs- OREGON STATE UNIVERSITY; Scott McLeod- WA DNR; Jerry Anderson, Scott Ketchum, Walt Shields- Forest Capital; Jeanette Griese- BLM; Robert Deal- PNW Research Station

The meeting started at 10:00 at the Cascade Head Experimental Forest headquarters. After welcomes and introductions, Andrew began 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 had less than the average amount of fieldwork. Measurements and various treatments were done on only 8 installations. Many thanks go out to all of the cooperators for providing crews and special thanks go out to the HSC Management Committee, for braving deep snow to measure the Type 1 installation outside of Darrington. Last years work included:

- Two Type 1 installations were measured. The 14th year measurement at Sauk River (MBSNF) and the 19th year measurement at Sechelt (BCMin).
- Five Type 2's had fieldwork. Maxfield Creek (WADNR) had its 12th year measure and one thinning treatment; LaPush (WADNR) had its 17th year measure and 3rd pruning lift; Pollard Alder (SNF) had its 17th year measure, 4th pruning lift, and the last thinning treatment; Lucky Creek (BCMin) had the second thinning treatment.
- One Type 3 installation (Cedar Hebo, SNF) had its 12th year measurement.

This coming year's fieldwork (Fall 2008- Spring 2009) will be a very busy year. A total of 11 installations need to be measured, 5 plots will need to be thinned and 4 plots will need to be pruned. Work will include:

- One Type 1 measurement.
- Three Type 2's will need their 12th year measurement.
- Five Type 2's will need their 17th year measurement.
- One Type 3 will need its 12th year measurement.
- One Type 3 will need its 17th year measurement.

Of note, there are four "orphaned" installations to be measured that do not have field crews available. These include:

- 2203-Pioneer Mtn.; Toledo, OR
- 3203-Sitkum; Coos Bay, OR
- 3210- Wrongway Creek; Blodgett Forest
- 5205- Tongue Mnt.; Gifford Pinchot NF

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

Concern was expressed about getting the "orphaned" sites measured. It was decided to use the next HSC Winter meeting as a "work party" to measure one of these sites. Forest Capital also suggested that they might be able to take over measurement responsibility for all of the ANE sites (2203, 2205, and 2302).

Andrew then briefly went over the "Regional Modeling Effort". This cooperative effort to create a red alder database is resulting in the creation of a new version of FVS. This 2008 variant will be a dramatic improvement of the older version since it will have 100 times the amount of data. Preliminary modeling work has commenced. For those interested in more details regarding this effort contact Andrew for a copy of his FVS data summary presentation and Connie Harrington's beta testing results presentation given at the WHC meeting on June 4, 2008).

- Despite a number of setbacks, work is still underway. As of this summer, three of the ten functional relationships (i.e. equations) have been refit (Height-Diameter, Bark Ratio, and Large Tree Diameter Growth) and preliminary testing of the "new" variant is underway. The scheduled completion date is uncertain because the FMSC has yet to determine the 2009 priority list/work schedule.
- Andrew then updated the group on the ORGANON modeling effort. The effort is divided into four main objectives. These are:
- Develop data sets that can be used to model the growth and yield of red alder in the Pacific Northwest. This step involves both data cleaning, transformation and synthesis.
- Use the pure red alder plantation data from the resulting modeling data sets,

to develop dominant height growth, largest crown width, height-diameter, height-to-crown-base, diameter growth rate, height growth rate, and mortality rate equations.

- Insert the resulting equations into ORGANON and evaluate the resulting stand level predictions from the model.
- Combine the natural stand red alder data from the regional red alder data base with the data sets previously used to model red alder in ORGANON, and re-calibrate the red alder equations (i.e., the height-diameter, height-to-crown-base, diameter growth rate, and mortality rate equations) currently found in the southwest Oregon, Northwest Oregon and SMC versions of ORGANON.

Work has commenced on the first three objectives. Of major importance is the creation of the dominant height growth equations. This has led to testing if the existing site index equations are adequate to describe plantation growth (and if not, to create new site index equations) and the possible effect of planting density on height growth. Completion of the first three objectives is forecasted for the end of 2008.

The HSC has acquired sufficient funds for at least the first year. Funds consisted of various contributions from interested agencies and companies and also from a Forest Service grant. Funding for the second year is not yet complete, but Dave is aggressively pursuing additional sources.

Dave then briefly went over the ORGANON modeling effort. Dave has acquired sufficient funds to start the modeling process. The first years' goals are to add the recent HSC data to the database, clean and format the database, and to investigate growth relationships. The second years' objectives are to develop all of the growth (and mortality) equations and to assemble the growth model. This will be done for both plantations and natural stands. Funding for the second year is not yet complete.

Next, the topic turned to the HSC budget. In regards to FY 2008, all members paid dues except for the Siuslaw national forest. That, with the additional dues from Forest Capital, allowed the HSC enough income to fund Andrew for 8 months. The balance of his time was made up for by external funding for the ORGANON. For FY 2009, it appears the Siuslaw National Forest and the Washington Hardwood Commission will not pay dues. This, in conjunction with increasing costs of measurements (gas, food, lodging, etc.) will result in enough income to only fund Andrew for 7 months. Once again, Andrew's time will be made up with the ORGANON modeling project.

The reduced time Andrew is spending on the HSC was concerning to all. There are two ways to increase the income; recruit new members and/or raise dues. Dave and Andrew have continuously been seeking new members and Dave asked all cooperators to check with their respective institutions about a potential dues increase.

To help identify what Andrew has time for and conversely what he is not able to accomplish with his reduced time, Dave and Andrew assembled a list of deliverables, what's being done, and what is not. This list was inadvertently left out of the packet so please see the attached document.

After lunch on the Cascade Head grounds, we traveled to Forest Capital property near Linclon City, OR. Here we focused on two main topics:

- Swiss Needle Cast's effects on forest management, the role of alder as an alternative species, Forest Capital's alder strategy, and alder site selection.
- A newly established alder plantation where we continued discussing alder site selection, lessons we've learned about plantation establishment, and early growth of alder plantations.

Discussion topics included:

- Forest capital owns approximately 140,000 acres in the Central Oregon Coast Range. Much of the property is affected by Swiss needle Cast (SNC).
- Forest Capital's main objective (like all industrial forest landowners) is to produce a rotation of valuable trees in as short of time as possible. This objective requires intensive management practices.
- Forest Capital's management strategy regarding reforestation is two-fold. First, using modeling tools, they identify areas of high incidence of SNC. Second, within those areas they identify sites suitable for hemlock or alder.
- Local sites not suitable for alder are sites exposed to salt spray and ridgetops exposed to high winds.
- When necessary, Forest Capital is also dividing up their harvest units to avoid planting alder on steep slopes and slopes with south aspects.
- Planning ahead for future logging logistics also plays a major consideration in choosing where to plant hemlock or alder.
- Observations at a newly planted alder unit include:
    - The chemical site preparation seemed extremely effective,
    - the bare-root 1-0 stock looked good; the roots were inoculated with *Frankia* and healthy buds were found along the entire stem,
    - some elk browse was observed as well as mortality from what we concluded was an extremely hot spell just after planting,
    - all-in-all the group concluded that Forest Capial's site selection criteria and reforestation practices are on target.

Wednesday July 9, 2008:

Attendees: Andrew Bluhm, David Hibbs- OREGON STATE UNIVERSITY; Scott McLeod, Chris Rasor- WA DNR; Doug Robin, Mitch Taylor, Joe Travers- OR Dept. of Forestry; Jerry Anderson, Scott Ketchum- Forest Capital; Jeanette Griese- BLM; Robert Deal- PNW Research Station; Glenn Ahrens- OREGON STATE UNIVERSITY Extension

The meeting started at 9:00 to tour Oregon Department of Forestry property. Here we visited three sites:

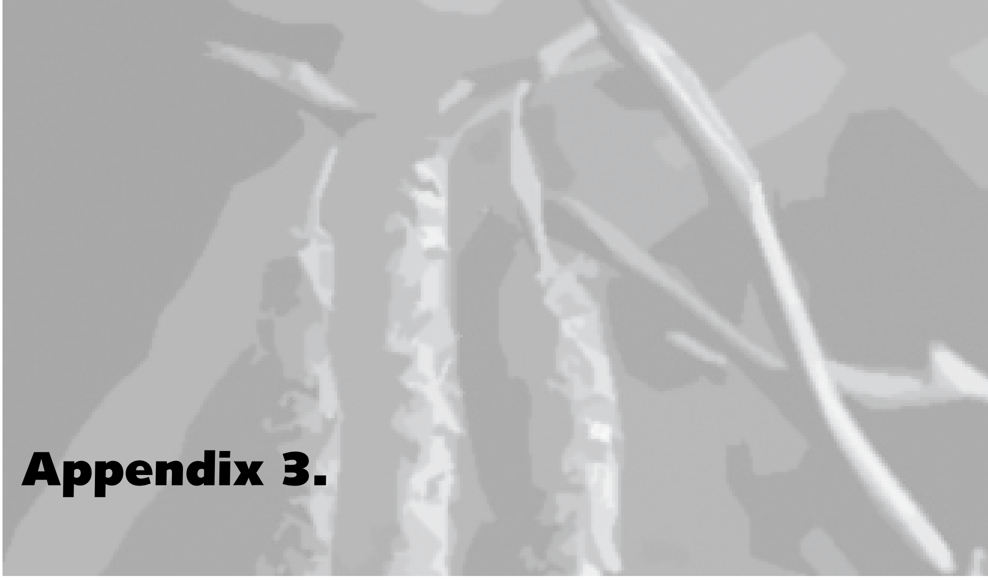
- A recently harvested unit to be planted with alder. There we will discussed the role of alder in *Phellinus* amelioration, the pros and cons of other alternative species, and continued discussion about alder plantation site selection, establishment, and growth.
- A 15 year old alder plantation where we discussed density management, commercial thinning, and differential plantation growth.
- A 5 year old mixed-species (alder/cedar) plantation where we discussed the role of mixed-species stands in terms of diversity and wildlife and how to address sub-par plantation performance.

Discussion topics included:

- A description/explanation of ODF's structure-based management strategy.
- Unlike most industrial forest landowners, ODF's objectives are many including; achieving desired structure and desired future conditions (DFC's), ameliorating disease, wildlife diversity, and producing a forest crop.
- Desired future conditions, how to define those, and how to achieve them.
- How to manage aging, senescent alder regenerated from the Tillamook Burn and "zombie" alder; alder that had been previously sprayed, yet not dead and not growing well.
- How to determine a "good" alder site. The advantages and disadvantages of Harrington's "A method of site quality evaluation for red alder".
- How to manage alder on poor to medium quality sites infected with *Phellinus* (i.e. planting density, timing/intensity of thinning, rotation age, etc).
- How to effectively address "intra-unit" variability in regards to alder growth and the necessity/timing of pre-commercial or commercial thinning.
- How to integrate Puettman's "Density Management Diagram" into an overall alder management strategy.
- The feasibility of commercial thinning in regards to initial planting density, growth rates, growth responses, log sizes/volume, and rotation length.

Many thanks go out to Jerry Anderson (Forest Capital) and Mitch Taylor (Oregon Department of Forestry) for logistics and presentation materials.

For more information or to receive the handouts associated with this meeting please contact Andrew Bluhm.



Appendix 3.

Financial Support Received in 2008-2009

Cooperator	Support
BC Ministry of Forests	$8,500
Bureau of Land Management	$8,500
Forest Capital	$8,500
Goodyear-Nelson Hardwood Lumber Company	$4,500
Oregon Department of Forestry	$8,500
Siuslaw National Forest	------
Trillium Corporation	------
USDA Forest Service PNW Station	In kind
Washington Department of Natural Resources	$8,500
Washington Hardwood Commission	$4,000
Subtotal	$51,000
Forestry Research Laboratory	$41,000
Total	$92,000

www.cof.orst.edu/coops/hsc/