Hardwood Silviculture Cooperative

Annual Report 1989-1990

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Highlights of 1989-1990

A workshop was held and a report prepared on "Red alder - guidelines for successful regeneration.

The existing alder database study was completed, including 1) validation of alder yield tables and growth models, 2) development of functions representing size/density relationships in natural alder stands, and 3) formulation and testing of growth models based on size/density relationships in mixed stands of alder and Douglas-fir.

The Red Alder Stand Management Study was given top priority, and the majority of our effort is now focused on establishing plantation installations for this study. The Final Draft of the Field Manual is complete. Five Type 2 installations (new plantations) and two Type 1 installations (thinning in existing stands) were established in spring 1990.

Cooperative membership increased greatly with the addition of the B.C. Ministry of Forests, Norvik Timber Inc., Forestry Canada, and the Oregon Department of Forestry. The Siuslaw National Forest and the Gifford Pinchot National Forest are now active participants in Cooperative studies.

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Introduction

The Hardwood Silviculture Cooperative has two general objectives: 1) to improve the information base for management of the hardwood resources of the Pacific Northwest, and 2) to provide information on hardwood management to its cooperators and to other resource managers. Red alder is currently the primary species of interest to the Cooperative.

One of our major projects was completed this year: modeling with the existing database for red alder. A catalog of permanent plot data for alder and mixed alder/conifer plots was completed last year. Using data from the catalog reports are complete for three major subject areas: validation of existing yield tables, analysis of size/density relations, and growth modeling in pure and mixed stands. Results from this work will provide a foundation for further development of growth and yield models for alder and alder/fir mixtures using data generated in other Cooperative studies.

HSC research is now concentrated on the Red Alder Stand Management Study, which was initiated last year. The Final Draft Field Manual was completed this year after revision based on our experiences with initial installation establishment. Three Type 1 (existing stand) installations and five Type 2 (new plantation) installations have now been established. Our efforts are focused on establishing alder plantations; to this end, great progress has been made in synthesizing current research and past experience on regeneration of red alder.

HSC membership increased this year with the addition of the British

Columbia Ministry of Forests, Oregon Department of Forestry, and Norvik Timber. The Siuslaw National Forest and the Gifford Pinchot National Forest have also become active participants in the Cooperative.

The Cooperative accomplishes its goals through research and education, under the guidance of its Policy and Technical Committees. The following report reviews the actions of these committees and the research and educational activities of the Cooperative in the last year.

Organizational Activities

Policy Committee meeting - June 1989

At our June meeting (Oregon State University, Peavy Lodge, Corvallis) the Policy Committee reviewed progress reports on the alder existing data base and stand management projects. Also, there was considerable discussion of potential directions for new research. Out of a list of potential topics, the committee selected two for further development and consideration by the Technical Committee. The meeting concluded with review and approval of the annual budget.

Technical Committee meeting - October 1989

The Technical Committee met on October 5 in Kelso, Washington. This meeting was combined with a workshop on alder regeneration. The workshop provided a forum for presentation and discussion of information on alder regeneration. This information had two major sources: 1) observations of

participating foresters based on their experience with intentional regeneration of alder, and 2) conclusions and guidelines based on research specifically addressing alder regeneration. Weyerhaeuser Co. research foresters shared results of 2 years of study on seedling culture and outplanting. Results of this workshop are summarized in a report titled "Red alder - guidelines for successful regeneration".

Cooperative members were also updated on the stand-modeling and stand management studies. There was review and discussion of two proposals for new research requested by the Policy Committee: 1) regeneration of alder from seed and 2) the effects of scattered alder in Douglas-fir plantations. After consideration of the current information, most Technical Committee members did not recommend regeneration from seed as a topic for new research. The committee recommended further development of a pilot study proposal for examining the effects of scattered alder in Douglas-fir plantations.

Policy Committee meeting - December 1989

At our December meeting (PNW research station, Olympia, WA) progress reports, budgets, and research proposals were reviewed.

With respect to new research, there was a general recommendation to concentrate efforts on establishing controlled study installations in an experimental context, rather than expending effort on extensive observational studies of existing plantations or stands. The Red Alder Stand Management Study was given top priority.

Cooperative Research

Cooperative research emphasizes Cooperative-funded studies of hardwood management.

Alder Stand Modeling using the Permanent Plot Data Base

In 1987, Ph.D. student Klaus Puettmann began a study of red alder growth utilizing permanent plot data provided by landowners from around the Pacific Northwest. The first step in this project was a survey of the data bases of existing permanent plots for red alder and mixed alder/conifer (completed Fall 1988). Using suitable plots from the data base, the project had two goals: 1) Evaluation of existing growth and yield tools for red alder and mixed alder/Douglas-fir stands and 2) development of new models describing growth and development of these stands. In the latter step, a growth simulator was to be developed to the extent permitted by the available data.

In the fall of 1989, the analysis of existing growth and yield tools was completed and reported to the Coop. This study evaluated Worthington's[1] (et al. 1960) normal yield tables, Chamber's[2] (1974) empirical yield tables, and the Stand Projection System[3] (SPS, Arney 1985).

[1] Worthington, N.P., F.A. Johnson, G.R. Staebler, and W.J. Lloyd. 1961. Normal yield table for red alder. USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon. Research Paper PNW-36. 32p.

[2] Chambers, D.J. 1974. Empirical yield tables for predominantly alder stands in western Washington. Washington State Department of Natural Resources,

Olympia. DNR Report 31. 70 p.

[3] Arney, J.D. 1985. SPS-stand projection system for mini- and micro-computers. Journal of Forestry. 83:378.

The comparison of the currently existing tools showed the weaknesses of the normal yield tables for use in individual stand predictions. The empirical yield table had a good accuracy of prediction for red alder in pure and mixed stands and was recommended for yield predictions. SPS showed problems with growth and mortality projection of pure and mixed stands, especially over a full rotation length.

The alder stand modeling project was completed in February 1990. A detailed description of the project is provided in Puettmann (1990) and journal manuscripts are being prepared. The modeling project included a pure Douglas-fir stand component to better model mixed-species stands. The first step was to model the size-density trajectories for both species in pure stands. Next, the self-thinning concept was expanded into a self-thinning surface to include mixed red alder/Douglas-fir stands. An investigation into stand dynamics established the major factors determining mixed stand development. These components were then combined into a stand simulator, which allows prediction of stand development.

In the analysis of single species stands, the shape of the size-density trajectory for red alder was determined to be independent of initial density and of the method of regeneration (natural versus planted). The establishment of a self-thinning line allowed the calculation of a relative density for red alder (actual

density/maximum density for the given diameter). Density dependent mortality started at a relative density of 0.44 throughout the range of densities available for analysis.

The self-thinning line for Douglas-fir was higher than the one for red alder and had a shallower slope (-0.525 for Douglas-fir versus -0.638 for red alder, see Figure 1). Also, Douglas-fir approached the self-thinning line in a steeper fashion. This indicated that Douglas-fir stands exhibit more mortality for a given diameter increment and that they stratify more extensively than red alder. Once density dependent mortality occurs in Douglas-fir stands, they quickly reach the self-thinning line.

The models developed for the pure species stands were used as a basis for analysis of the size-density trajectory for mixed stands. A parameter adjusting the slope of the self-thinning line for species proportion was incorporated into the model of the size-density relationship. This expanded the self-thinning line into a self-thinning surface (Figure 2). The self-thinning surface showed a planar region for stands with high and medium proportions of red alder. The region for stands with a higher proportion of Douglas-fir bend in a curvilinear fashion toward the Douglas-fir line. Red alder has a dominating influence on the size-density relationship if it is a substantial proportion of the stand.

An analysis of the underlying stand mortality and shift in species proportion of mixed stands explained the dynamics underlying development of individual stands along a size-density trajectory. The major factors driving mortality pattern

are stand density and relative dominance of the species. The mortality of the Douglas-fir component was determined by the proportion basal area in Douglas-fir, stand density, and the Douglas-fir site index. The shift in basal area proportion is determined by the current species proportion, the relative dominance of the species, and stand age.

This information was then combined into a stand simulator in the following fashion. The size-density relationship determined the pattern of development and the dynamic components determined the speed of development on this pattern. Comparison of stand simulations with actual stand development showed a good representation of stand dynamics. However, it also indicated the need to focus research on development of young mixed stands (the mixed species data set covered the age range of 20 to 70 years), the effects of relative size of each species, site index, and the incorporation of management practices.

Figure 1. Projected size-density trajectories for red alder and Douglas-fir for stands initiated at 1000, 4000, 8000, and 12,000 trees per hectare, projected to 100 trees per hectare.

Figure 2. Expansion of the self-thinning line to a self-thinning surface for pure and mixed stands.

Alder Stand Management Study

The alder stand-management study was initiated in July 1988 with the general goal of improving the information base for management of alder stand density and composition. Two major approaches are incorporated in the plan: 1) manipulations in existing stands (Type 1 installations) and 2) manipulations of new plantations (Type 2 installations). Intensive reconnaissance efforts have shown an inadequate number of young alder stands suitable for Type 1 installations. The extra effort required to create (or allow) suitable natural stands to develop into Type 1 candidates is better spent establishing Type 2 installations, which provide better quality data. Therefore most efforts are now concentrated on establishment of alder plantations.

Our goal for 1990-1994 is to establish 6 Type 1 installations and 22 Type 2 installations. Installations of both types will be stratified by physiographic region (Figure 3) and alder site index class. Thinning will be done at each of three different ages of entry: 1) age 3 to 5 years, 2) when trees have 4.6 to 6.1 m (15 to 20 ft.) height-to-live-crown, and 3) when trees have 9.1 to 9.8 m (30 to 32 ft.) height-to-live-crown. Respacing densities for these entries are shown in Table 1.

The Cooperative is also interested in establishing controlled mixtures of red alder and Douglas-fir on sites where productivity is low due to low available nitrogen supplies (Douglas-fir site class III and IV).

Our long term goal is to establish 9 mixed alder/Douglas-fir installations in a replacement series experimental design.

Major activities in 1989-1990 included:

1) Establishment of two Type 1 and five Type 2 installations (see Table 2).

2) Revision of the Field Manual and completion of the Final Draft.

3) Continued reconnaissance for future installation sites.

4) Synthesis of information on alder regeneration and preparation of a report "Red alder - guidelines for successful regeneration".

5) Formulation of specific goals and expectations for installation establishment for each Cooperator.

Figure 3. Climate and physiographic regions for the Pacific Northwest. Adapted from "Natural vegetation of Oregon and Washington", J.F. Franklin and D.T. Dyrness, 1973. USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon. Gen. Tech. Rep. PNW-8. and "Biogeoclimatic zones of British Columbia",

Table 1. Initial densities and respacing densities in trees per hectare (trees per acre) for Type 1 (natural) and Type 2 (planted) alder research installations.

Age or Height-to-live crown at entry	Density tph (tpa) Initial (natural)	Respacing	Initial (planted)	Respacing
3-5 years	> 1605 (650)	568 (230)	1297 (525)	568 (230)
	> 1605 (650)	1297 (525)	2967 (1200)	568 (230)
4.6-6.1 m (15-20 ft)	> 1605 (650)	568 (230)	1297 (525)	568 (230)
	> 1605 (650)	1297 (525)	2967 (1200)	568 (230)
9.1-9.8 m (30-32 ft)	> 717 (290)	247 (100)	1297 (525)	568 (230)
	> 717 (290)	568 (230)	2967 (1200)	568 (230)
Unthinned	> 1605 (650)	-	247 (100)	-
	> 717 (290)	-	568 (230)	-
			1297 (525)	-
			2967 (1200)	-

Table 2. Red alder stand management study installations by year, Region, and Cooperator.

Type 1 installations

Installation #	Year	Region	Location	Cooperator
4101	1989	4	Seshelt, B.C.	B.C. Ministry of Forests
2101	1990	2	Beaver, OR	Siuslaw National Forest
4102	1990	4	Sedro Wooley, WA	Washington DNR

Type 2 installations

Installation #	Year	Region	Location	Cooperator
4201	1989	4	Sedro Wooley, WA	Goodyear Nelson Hardwood Lumber Co.
4202	1990	4	Sedro Wooley, WA	Goodyear Nelson Hardwood Lumber Co.
3201	1990	3	Philomath, OR	Siuslaw National Forest
3202	1990	3	Longview, WA	Weyerhaeuser Company
2201	1990	2	Aberdeen, WA	Weyerhaeuser Company
5201	1990	5	Packwood, WA	Gifford Pinchot Natl. Forest

Substantial editing and revision of the Field Manual has occurred since the first draft in January 1989. After our experiences with the first installations, we made a summary of major issues pertaining to experimental design and installation establishment protocol (sent to the Technical Committee for review in February 1990). Appropriate revisions have been made and the Final Draft is available on request.

The field manual contains standard forms and specific instructions for field records of pre-establishment, establishment, and remeasurement surveys. Computer input and data storage formats for each form type have been established and documented (using Foxbase[4] software) in cooperation with the Forest Science Department Quantitative Sciences group at OSU. Computer programs for producing remeasurement data forms containing previous data and identifiers are currently written for SAS[5] statistical software for use with ASCII (American National Standard Code for Information Interchange) or SAS data files.

[4] Foxbase Software Inc., Perrysburg, Ohio.

[5] SAS Institute Inc., Cary, North Carolina.

Specific goals and expectations have been formulated for each Cooperator to help ensure that the Region-by-Site Index sampling matrix is filled from the diverse Cooperative ownerships.

Our managed-stand growth-and-yield models will be derived from the

basic size/density relationships developed from our alder stand-modeling study and the new data base being produced by this study. Although it will take many years for new plantations to produce the complete data set, preliminary analytical models have been formulated. Model development and testing will proceed using data from the permanent plot data base and Type 1 installations.

Ultimately, this study will produce the first growth-and-yield model for managed alder stands over a wide geographic range. The early stages of this study have already produced important syntheses of operational and theoretical information about alder regeneration and stand management.

Other Applied Research

This research is of interest to, but usually not funded directly by, the HSC. Cooperative members and their associates participate at their discretion through donations of land, labor or facilities.

Riparian Zone Management Study (COPE)

It has become increasingly clear that deliberate management of riparian vegetation is necessary to maintain riparian resource values. Without any management in riparian buffer strips, the initial riparian tree community in the Coast Range can be replaced by a shrub-dominated community. Little or no natural tree regeneration is found. Management of riparian areas may increase the effectiveness of the buffers for maintaining fish, wildlife and water quality

resources while utilizing the timber resource. As part of the COPE (Coastal Oregon Productivity Enhancement) program, several investigators, lead by David Hibbs, have begun a 6-year study of the dynamics of riparian areas with an emphasis on exploring management alternatives for optimizing the many riparian resources. The study is divided into 3 parts. These are:

1. A chronosequence examination of buffer strip conditions in relation to management activities, geography, and vegetation characteristics.

2. Development of tree regeneration systems through the use of replicated seedling trials with several levels of overstory and understory manipulation.

3. Develop a methodology for decisions concerning management for diversity and optimization of resource values.

At present, the study plan for Objective 1 and 2 is in the final stages of review. A study plan for Objective 3 will be developed at a later date. Study sites for the chronosequence sampling are being located and field sampling should begin this season. This year's sampling will focus on hardwood riparian communities. Conifer communities will be sampled in subsequent years.

One study site for Objective 2 has been located in the Green River area

south of Lobster Creek in the Central Coast Range. An additional study site should be identified by this time next year. Planting on these sites should begin next year with a mixture of five softwood and hardwood species.

Streamside Hardwood Filter Belts

Streamside areas in the Pacific Northwest are frequently under cultivation or pasturage. These practices have reduced or eliminated streamside cover, increased bank erosion, and increased nutrient inputs into the stream. All of these factors adversely affect water quality and fish production. In an attempt to counter some of these negative effects, a COPE funded project headed by Jim Sedell (PNW), Bill Emmingham, David Hibbs, and Stan Gregory is investigating the practice of establishing wooded strips along streams. The objective of the project is to determine if hybrid cottonwood and red alder can provide a buffer zone that absorbs nitrogen, improves groundwater quality, and yields a harvestable wood fiber crop.

The immediate objective of the study is to establish field plots along streams emptying into Oregon bays and the Pacific Ocean. Through a series of meetings with the Oregon Dairy Cooperatives, a suitable study areas have been located. An installation near Oregon State University has already been planted with both alder and cottonwood. Another installation was completed near Tillamook, Oregon last year. Pretreatment groundwater samples have been obtained and analyzed. A third installation will be located near Tillamook and a fourth near Coos Bay, Oregon.

Response of Red Alder to Intraspecific Competition

Competition between individual trees in a stand is important in determining the growth and form of the trees. Trees shift carbon allocation patterns in order to optimize resource acquisition. By understanding the way in which trees respond to different levels of competition, managers have the ability to produce those carbon allocation patterns which are the most useful to them. Management of red alder is a relatively new silvicultural option. Because of this, there is a need for basic information on the carbon allocation response of red alder to competition, in order to best utilize the red alder resource. This study (Giordano 1990) was designed to provide information on the mechanics of the competitive process and the effect of competition on aboveground tree growth, focusing specifically on red alder.

Plots with a wide range of spacings (101,00 to 238 trees per hectare) of red alder seedlings were planted in 1983 in the Cascade Head Experimental Forest on the central Oregon Coast Range. Growth characteristics such as tree height, tree diameter, branch length and branch diameter, were measured on trees at several spacings at 2 week intervals from March 22, 1988 to October 9, 1988. These measurements were used to calculate relative growth rates of whole trees and their various growth components, such as branches and leaves, for each 2 week interval. Results of these calculations were then used to relate tree spacing to tree growth in order to examine how red alder adjusts its morphology in response to competition (Figure 4).

This study showed that red alder growth rates were extremely sensitive to spacing. There was a five-fold difference in yearly relative growth rate at the most narrow spacing (RGR = 0.53; 101,000 trees per hectare) compared to the widest spacing (RGR = 2.39; 238 tph). Trees at intermediate spacings (13,600 trees per hectare) achieved the highest aboveground biomass production rate of 19 metric tons per hectare per year. These trees also allocated a large proportion of their total biomass (84%) to stemwood production although their net stem biomass growth was less than the next widest sample spacing. These preliminary results suggest that on good sites such as Cascade Head, management of red alder at intermediate spacings (4,000 to 8,000 trees per hectare) can achieve goals of both pulp production and solid wood production.

Figure 4. Red alder leaf area in the upper, middle, and lower sections of sample trees in relation to initial spacing (trees/hectare).

Cottonwood Clonal Screening in the Willammette Valley

In the spring of 1991, a 10-acre cottonwood clone screening and growth and yield study will be installed near Corvallis in the central Willammette River valley. This study is led by David Hibbs and funded by the OSU College of Forestry Research Forest.

The screening trial will include 10 to 12 new clones that have not yet received extensive field testing. Most of the clone material will be supplied by the joint University of Washington - Washington State cottonwood breeding program.

The growth and yield trial will examine the performance of 10 clones in the Willammette Valley climate zone on river front soils. To date, there is very little publicly available growth and yield information on the Populus trichocarpa x deltoides hybrids being used industrially in the Pacific Northwest and none for the Willamette valley.

For demonstration purposes, this research installaton will also include planting of the native black cottonwood and plots that will demonstrate the importance of competition control during plantation establishment.

Basic Research

Basic research explores fundamental principles pertinent to hardwood silviculture. These studies provide a basis for future applied research, ideally leading to innovative technology and better management. Most basic research is conducted by graduate students with funding from outside the HSC, although

Cooperator participation is encouraged. Basic research projects conducted by graduate students associated with the Cooperative are listed in Table 3.

Table 3. Research projects of graduate students.

Student	Degree	Project description	Study location	Expected completion
Peter Giordano	M.S.	Density effects on growth and biomass allocation of red alder	Cascade Head Exp. For.	8/89
Seng-Jun Lu	M.S.	Water relations of red alder	Cascade Head Exp. For.	9/89
Sang Kyun Kim	M.S.	Comparative effects of thinning on red alder and Pacific madrone	W. Oregon S.W Oregon	9/90
Cynthia Froyd	M.S.	Growth and vegetation dynamics in riparian buffer strips dominated by red alder	W. Oregon	9/91

Educational Activities

HSC Reports

The Cooperative produces reports and other documents for its members. Four were produced this year:

Comparison of stand characteristics from long-term remeasured plots of red alder with yield table and growth model predictions

The Size-Density Relationship in Pure and Mixed Red Alder/Douglas-fir stands and its Use in the Development of a Growth Model. Ph.D. thesis:

Red alder: guidelines for successful regeneration

Red alder stand management study field manual: final draft

Workshops

Red alder regeneration

Attendees of the October Technical Committee meeting participated in an informative tour of James River Company hybrid poplar fiber farms and Dean DeBell's 15-year-old alder plantings near Apiary, Oregon. A workshop on alder regeneration was held as part of the meeting on the second day.

Hardwood management training

David Hibbs (OSU) and Joe Misek (Oregon Department of Forestry) conducted a one and a half day training program for Oregon Department of Forestry Service Foresters and OSU Forestry Extension agents. The program covered the new legislation allowing tax credits for hardwood regeneration and the basic ecology and management principles for the major hardwood species of Oregon.

Hardwood Forest Products Resources Committee

Under the direction of the Oregon Department of Forestry's Hardwood Forest Products Resources Committee (HFPRC), David Hibbs organized a workshop of 35 management-level representatives of organizations concerned with land management issues to discuss the hardwood resource and its future. Following presentation of background information, the workshop broke up into working groups to focus on specific issues and to develop recommendation for their resolution. After reforming as a whole, the workshop reviewed the individual groups recommendations and developed a set of recommendations for the whole workshop. These have been summarized in a report to the HFPRC and are available.

Presentations

Red alder regeneration and management with emphasis on areas infected with Phellinus root rot. Glenn R. Ahrens. Gifford Pinchot National Forest annual reforestation meeting. Vancouver, Washington, March 1990.

Establishment and management of alder and poplar in the Pacific Northwest. Glenn R. Ahrens. Presentation for Washington DNR. Chehalis, Washington. February 1990.

Development of the size-density surface for mixed red alder/Douglas-fir stands. Klaus J. Puettmann, D.E. Hibbs, and D.W. Hann. Annual meeting

of the Northwest Scientific Association. Corvallis, Oregon. March 1990.

The role of water stress in mediating intraspecific competition among red alder trees. Peter Giordano and D. E. Hibbs. Annual meeting of the Northwest Scientific Association. Corvallis, Oregon. March 1990.

Long-term management of riparian vegetation for multiple objectives.

David E. Hibbs. Silvicultural management of riparian areas for multiple resources. A COPE workshop. Glenden Beach, Oregon. December 1989.

Implications of three alternative timber harvest patterns for other resources; forest regeneration and wood production. David Hibbs.

Wildlife diversity and landscape pattern in northwest coastal forests. COPE workshop, Newport, Oregon. September 1989.

Direction for 1990-1991

- Develop reports from stand modeling project
- Establish two type 1 and four type 2 installations in the Stand Management Project

- Initiate a new short-term project
- Conduct a symposium on alder biology and management in cooperation with the USFS PNW Research Station
- Continue growth of the Cooperative

Membership in the Cooperative almost doubled in the last year. This increase in resources has allowed the schedule of installations to be accelerated. Great progress has been made in organizing older members and bringing new members up to speed in the Stand Management Study. A schedule of installations for each member has been established. This schedule will challenge both the Cooperative and individual members.

Cooperative members should feel proud of the role they have played in Oregon's new legislation allowing tax credits for hardwood regeneration. The presence and activities of the Cooperative underscored the interest and importance of the issue and thus helped convince legislators of the value of the legislation.

Appendix 1: Publications

Emmingham, W., Bondi, M. and D. E. Hibbs. 1989. Underplanting western hemlock in a red alder thinning: early survival, growth, and damage. New Forests 3:31-43.

Giordano, P. A. 1989. Growth and carbon allocation of red alder seedlings grown over a density gradient. M.S. Thesis, Oregon State University, Corvallis, OR. 129 p.

Hibbs, D. E., and A. A. Ager. 1989. Red alder: Guidelines for seed collection, handling, and storage. Special Publication 18. Forest Research Lab, Oregon State University, Corvallis, Oregon. 6 p.

Hibbs, D. E. and G. C. Carlton. 1989. A comparison of diameter- and volume-based stocking guides for red alder. West. J. Appl. For.
4(4): 113-115.

Hibbs, D. E., and K. Cromack, Jr. 1990. Actinorhizal plants in Pacific Northwest forests. In C. Schwintzer and J. Tjepkema (eds.), The Biology of Frankia and actinorhizal plants, pp. 343-363. Academic Press, New York.

Hibbs, D.E., Emmingham, W., and M. Bondi. 1989. Thinning red alder: Effects of method and spacing. For. Sci. 35(1): 16-29.

Lu, S. 1989. Seasonal and diurnal trends of leaf water conductance of red alder (Alnus rubra Bong) growing along a density gradient in western Oregon. M.S. Thesis. Oregon State University, Corvallis, Oregon. 95 p.

Peterson, W. C. and D. E. Hibbs. 1989. Adjusting stand density management guides for sites with low stocking potential. West. J. Appl. For. 4(2):62-65.

Puettmann, Klaus. 1990. The size-density relationship in pure and mixed red alder/Douglas-fir stands and its use in the development of a growth model. Ph.D. Thesis. Oregon State University, Corvallis, Oregon. 178 p.

Appendix 2: Financial Support Received in 1989-1990

Cooperator	Support
Bureau of Land Management	$5,000
British Columbia forest Service	5,000
Diamond Wood Products, Inc.	3,000
Forestry Canada	3,000
Gifford Pinchot National Forest	5,000
Norvik Timber Inc.	5,000
Oregon Department of Forestry	5,000
Siuslaw National Forest	4,700
Goodyear-Nelson Hardwood Lumber Co.	3,000
University of Washington[1]	-
USDA Forest Service Pacific Northwest Research Station[1]	-
Washington Department of Natural Resources	5,000
Weyerhaeuser Company	5,000
Subtotal	$48,700
Forest Products Laboratory, OSU	37,900
Total	$86,600

[1] In-kind contributions.