FOREST RESEARCH LABORATORY
OREGON STATE UNIVERSITY

CRAFTS

Annual Report 1987-1988

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CRAFTS

Coordinated Research On Alternative Forestry Treatments & Systems

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CRAFTS HIGHLIGHTS

This report covers the eighth year of activity by the CRAFTS program on forest vegetation management. Highlights of this past year include the following:

- A diagnostic model for predicting the influence of competitors on Douglas-fir is being developed.
- Dan Opalach joined CRAFTS to coordinate efforts on the diagnostic model.
- Analysis of Douglas-fir growth in the Coast Range Release Study revealed interesting effects of competing vegetation on height and stem diameter.
- The second year of a study of methods to control sprout clumps of bigleaf maple was completed. Successful control strategies are emerging.
- The effect of sprout clumps of bigleaf maple on the wood yield of Douglas-fir is being determined.
- A computerized system for prescribing vegetation management treatments is being developed.
- Five CRAFTS Technical Reports were prepared and distributed. A field tour to observe how vegetation management is both studied and practiced was sponsored by CRAFTS for Cooperators.

INTRODUCTION

The purpose of the CRAFTS program is to provide leadership and direction within the discipline of forest vegetation management. The Cooperative also provides information to its members and others about such management in the Pacific Northwest. CRAFTS initiates research in young conifer plantations and conducts educational activities at Oregon State University. A forum for research coordination and information exchange among participating organizations is also provided.

The 1987-88 period was productive for the Cooperative. Several new projects were established, while others are nearing completion. It was decided

that CRAFTS should undertake the development of a region-wide diagnostic model for predicting the influence of competing vegetation on young Douglas-fir. Outside funding that augmented the commitment already made by CRAFTS for this project was obtained. Work began on the model in fall 1987. Dan Opalach was hired to coordinate that project.

CRAFTS has completed the fifth year of the Coast Range Competition Release Study. Long-term measurements will continue to be made every fifth year. A study to determine the impacts of bigleaf maple on Douglas-fir yield is well underway. Cooperators collected a significant amount of data for this project. The efficacy of herbicides and manual cutting in controlling sprout clumps of bigleaf maple was also assessed. Because of the success of an annotated bibliography on prescribed fire, the Cooperative is now considering a short-term literature search on how herbaceous vegetation and forage seedings affect conifer growth in plantations.

One of the ways the Cooperative accomplishes its informational and leadership goals is through research. This research is conducted under the guidelines outlined in our updated prospectus and through consultation with the Policy and the Technical Committees of the Cooperative. The degree to which members participate in the research varies according to the type of study. The three types of studies in the Cooperative are *applied, adaptive,* and *basic.*

APPLIED RESEARCH

Applied studies are developed and funded directly by the Cooperative. These studies assess methods for suppressing competing vegetation through site preparation and competition release. The causes for

the response of brush, trees, and herbaceous plants to these methods of control are also determined.

Coast Range Competition Release Study

By 1987, 5 years had elapsed since treatments were applied in the Coast Range Competition Release Study. The data from the study are currently being summarized in a manuscript that will be reviewed by cooperators and submitted for publication in a scientific journal. Some of these results follow.

Responses of the competing vegetation to treatment.--Responses of five associated shrub and hardwood species to the various competition-release treatments were monitored (Figure 1). Percentages of change in crown volume before and at yearly intervals after treatment were contrasted with those for the untreated control.

For salmonberry, crown volume was significantly reduced from pretreatment levels during each of the 3 years following application of Roundup® or complete removal of competitors. In contrast, Roundup® caused significant decreases in the crown volume of thimbleberry only in the first year after application. By the third year, the percentage increase in thimbleberry's crown volume over pretreatment levels exceeded 150 percent for all treatments except early Spring application of Garlon 4® to the foliage and complete removal of the competitors.

Crown volume of vine maple was significantly reduced from pretreatment levels through the second year after each of the release treatments (manual cutting, application of Garlon 4® in the dormant season, early application of Garlon 4® to the foliage, and complete removal of the competitors). However, by the third year, only complete removal resulted in a significant reduction in crown volume. Crown volume of bigleaf maple was

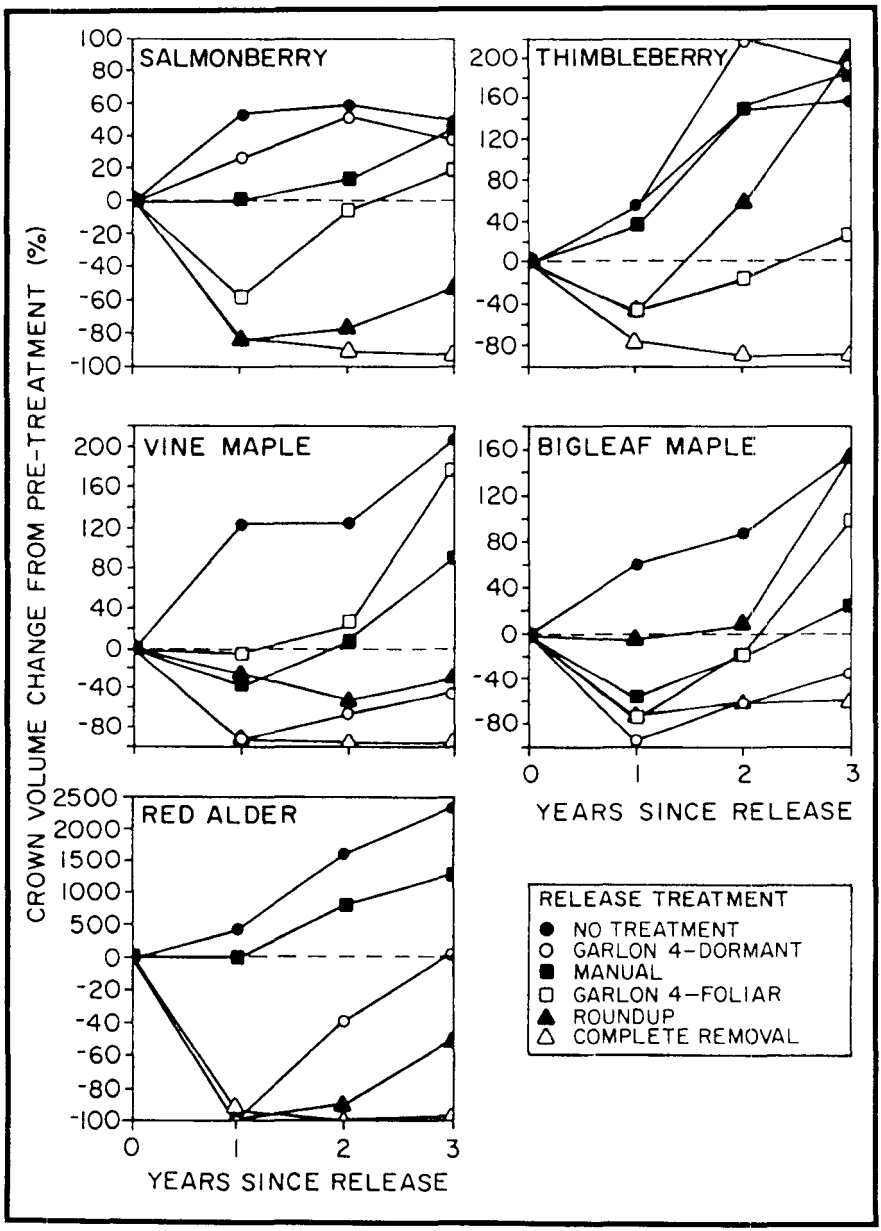

FIGURE 1.--Recovery of five shrub and hardwood species 3 years after six competition-release treatments were applied in the Oregon and Washington Coast Ranges.

significantly reduced 1 year after manual cutting, application of Garlon 4® in the dormant season, and complete removal. By the third year after treatment, however, reductions in crown volume were no longer significant.

Statistical comparisons of treatments were not possible for red alder, as it occurred at only one site when the study was initiated. In general, application of Roundup® and complete removal caused marked reductions in crown volume of red alder. Increases in crown volume on the manually cut and control plots exceeded pretreatment levels ten-fold by the third year of the study.

Responses of Douglas-fir to competition release.--Regression models have been developed that describe the observed growth responses of Douglas-fir to the treatments. These models describe two aspects of tree growth that act in combination to cause differences in absolute tree size. The first--a positive relationship between Douglas-fir height or stem diameter increment and previous-year size--establishes tree growth potential. The second is the fact that abundance and proximity of competing vegetation cause reductions in potential height or diameter increment.

Diameter increment of Douglas-fir was significantly influenced by both total cover of competing vegetation and degree of overtopping by shrubs and hardwoods. In the first year after treatment, effects from cover and overtopping were small. In the second and third years after treatment, the competitive effects from total cover and overtopping became more important. The diameter increment for each of the release treatments provides a convincing explanation for the mean growth responses that have been observed among treatments and reported in earlier CRAFTS Technical Reports. Although the percentage of overtopping declined after most of the release treatments were

applied, only complete removal of competitors caused a reduction in total vegetation cover as well.

Height increment of Douglas-fir was influenced only by percentage of overtopping, not by total vegetation cover. The increasing importance of overtopping with time since treatment is evident.

The regression equation describing diameter and height increment combines two influences on current-year tree growth--previous-year tree size and competition. Figure 2 displays simulations of these regression models for Douglas-fir growing under constant competition regimes; note that tree size following a given growing season is allowed to affect predictions of the next year's growth.

In these simulations, the compounding effects of previous-year tree size and competition on absolute tree size is evident. Trees under a low competitive influence are growing on steeper exponential trajectories than those growing with high levels of vegetation cover or overtopping. In addition, overtopping at high levels of total vegetation cover causes additional reductions in the rate of diameter growth (Figure 2a). The height simulations (Figure 2b) do not show large growth reductions from overtopping, probably because of the limited range of overtopping levels in the study.

Controlling Sprout Clumps of Bigleaf Maple

Second-year results were collected from a comparative study of various treatments to control sprout clumps of bigleaf maple in young Douglas-fir plantations. The study was installed in 1985 and 1986 on six sites provided by CRAFTS cooperators in Oregon and Washington. Six herbicides (Garlon 4®, Garlon 3a®, Roundup®, Escort®, Arsenal®, Weedone 170®) were applied three times a year (June, August, and February) by each of four methods: (1) foliar spray, (2) basal spray, (3) thinline

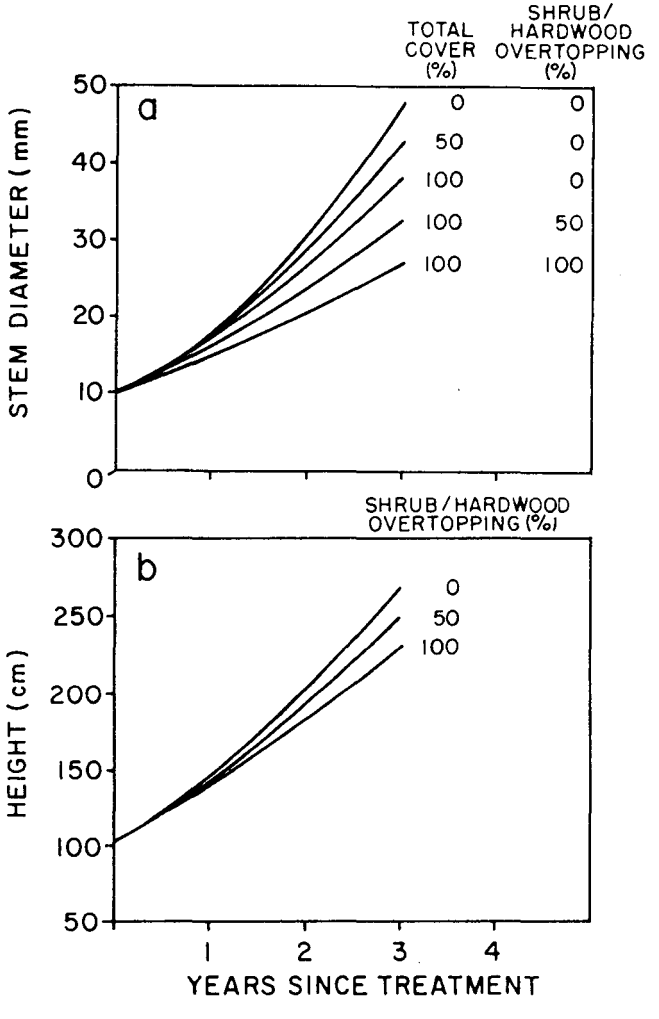

FIGURE 2.--Simulations of the regression models for (a) diameter and (b) height of Douglas-fir under constant competition regimes. Tree size is simulated as the function of previous-year tree size and competitive regime in the Oregon and Washington Coast Ranges.

(herbicide applied in a thin stream directly to the bark), and (4) cut-surface (herbicide applied to the cambium of a freshly cut stem). Manual cutting three times a year was also included in this experiment.

The change in effective crown volume (physical crown volume X percentage of foliage cover) of each clump relative to the pretreatment condition was used as the measure of treatment effectiveness. Second-year results were correlated with those reported the first year. Nearly all clumps exhibited less injury at the end of the second year than during the first year; however, treatments that provided good control in the first year tended to provide good control through the second year.

The most effective treatments (yielding about 85 percent or greater reduction in effective crown volume) at the end of the second year were (1) Arsenal® foliage sprays, (2) 3 percent Garlon 4® basal spray in February, (3) Garlon 4® thinline in August and February, (4) Weedone 170® basal spray in August and February, and (5) manual cutting with a Garlon 3a® stump application. The other treatments in the study allowed substantial recovery of effective crown volume by the end of the second year. Details of the second-year results were presented by Bob Wagner at the April Technical Committee meeting and will be reported in an upcoming CRAFTS Technical Report.

Assessment of injury to Douglas-fir seedlings within 15 ft of the bigleaf maple sprout clumps indicated that most of the treatments were not injurious to the seedlings. The only treatments that injured more than 20 to 30 percent of the surrounding Douglas-fir seedlings were foliar sprays of Roundup®, Arsenal®, and Escort® in June. Douglas-fir was not injured when these treatments were delayed until August, and the later applications did not substantially alter treatment effectiveness on bigleaf maple.

Since triclopyr (Garlon 4®) is commonly used to control sprout clumps of bigleaf maple in the Pacific Northwest, first-year results from treatments with this herbicide were analyzed in detail to determine which factors influenced its delivery and effectiveness. Results described in a recent CRAFTS Technical Report revealed that the rate of triclopyr delivery (measured in grams of triclopyr a.e. per square meter of crown area) was influenced primarily by the method of application, clump size, and other clump characteristics. The rate of triclopyr delivery and season of application determined the degree of treatment effectiveness. This analysis indicated that differences in treatment effectiveness among seasons of application were eliminated when more than 4 ml of Garlon 4®/m^2 of crown area was applied (Figure 3). The dose-response curves indicate why the effectiveness of the 3 percent Garlon 4® basal spray was more influenced by season of application than was the Garlon 4® thinline treatment. In addition, no differences between the 3 percent Garlon 4® basal spray and Garlon 4® thinline treatments were detected when the rate and season of triclopyr application were held constant.

The third and final year of results from this study will be collected by CRAFTS personnel and cooperators this summer.

How Sprout Clumps of Bigleaf Maple Affect Douglas-fir Yield

Research is underway by CRAFTS on how crown development of bigleaf maple sprout clumps affects wood volume of surrounding Douglas-fir through age 60. The objective of this study is to determine how much area is lost to Douglas-fir volume production because of a single sprout clump and, with this information, to determine the economic thresholds for controlling individual clumps. The study is divided into two phases.

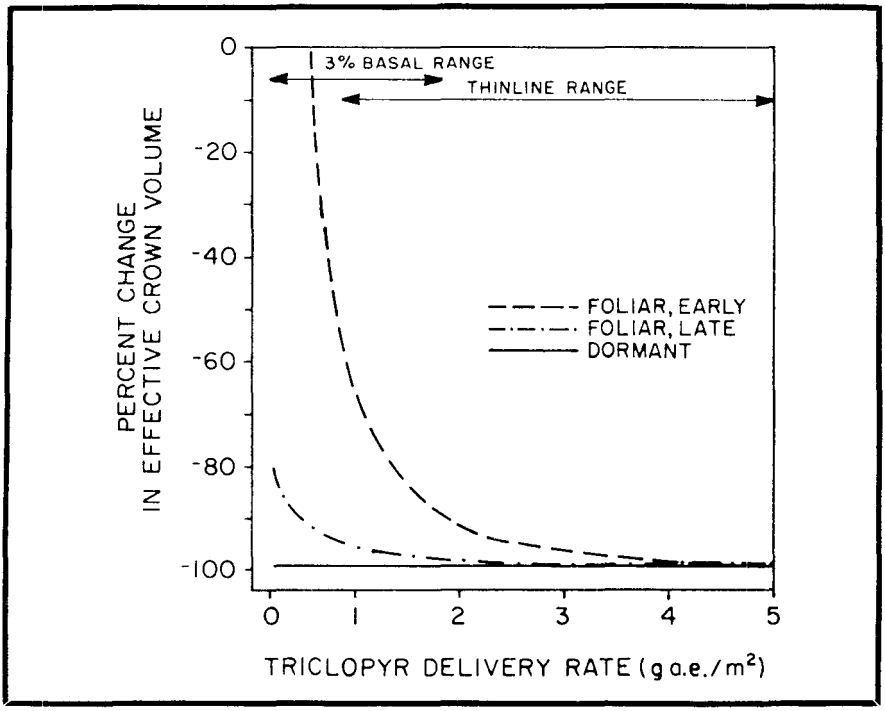

FIGURE 3.--The relationship between the percentage of change in effective crown volume of bigleaf maple sprout clumps the first year after treatment and the rate of triclopyr delivery during three different seasons of application. The regression model was derived by combining data from the 3 percent basal and thinline treatments; results are presented as an average among study sites. The range of triclopyr delivery rates for each treatment is indicated.

Phase I: Predicting crown development of young bigleaf maple sprout clumps.--Regression equations are being developed to describe the growth of bigleaf maple sprout clumps 1 to 10 years after harvest. Two approaches based on data collected by CRAFTS cooperators are being used to examine regression models for their suitability in predicting crown width and height of bigleaf maple: (1) relationship of absolute clump size to age,

stump size, and site factors, and (2) relationship of previous clump height (estimated with stem reconstructions) to age, stump size, and site factors. The first approach has been followed in developing a regression model to predict crown width of bigleaf maple (adjusted $R^2 = 0.68$).

In this model, age of sprout clumps accounts for 45 percent of the variation in crown width of bigleaf maple. Various aspects of stump size were found to be important determinants of crown width. Average diameter of parent tree stumps (Figure 4a), the most important aspect of stump size tested, accounted for 12 percent of the variation in crown width.

Average stump height accounted for 5 percent of the variation in crown width of bigleaf maple (Figure 4b). Stump height may influence crown width because bigleaf maple sprouts tend to originate largely from aboveground portions of parent stumps. Thus, silvicultural opportunities may exist for limiting crown width by reducing stump height. Number of parent stumps was another significant variable (Figure 4c); however, it accounted for less than 1 percent of the additional variation in crown width.

Site factors accounted for 6 percent of the variation in crown width. From the locations of the study sites, variables were developed to describe latitude and longitude. After the effects of age and stump size were accounted for, crown width of bigleaf maple was found to be negatively correlated with elevation and relative location east of the Willamette meridian (i.e., sites in the Oregon and Washington Cascade Range). In addition, crown width of bigleaf maple was negatively correlated with estimates of King's site index.

Phase II: Predicting wood volume reductions.--The second phase of this study involves extending the

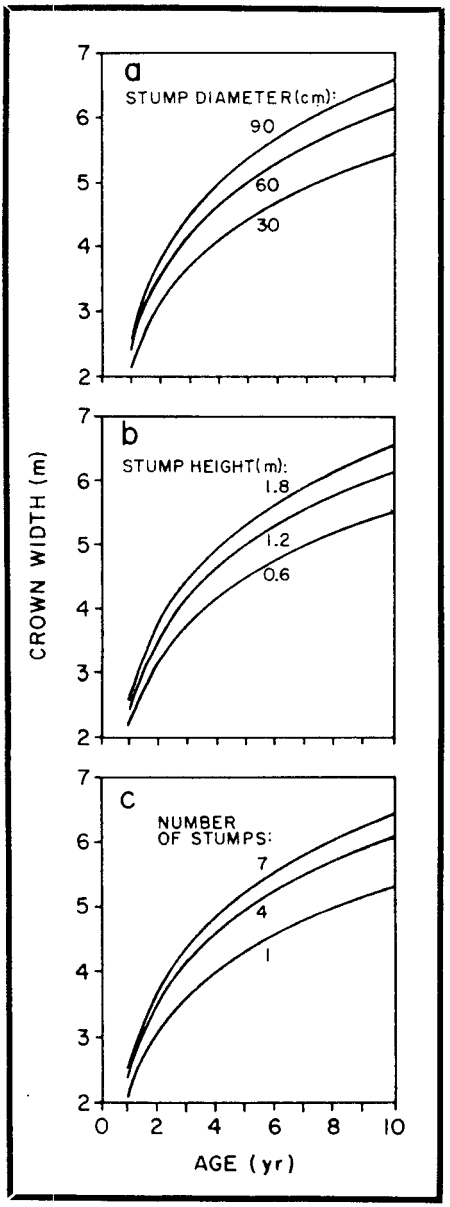

FIGURE 4.--How (a) diameter, (b) height, and (c) number of parent tree stumps affect crown width of bigleaf maple sprout clumps.

growth curves for crown area of bigleaf maple, as developed through age 10 in Phase I, so that they apply to maple growth in Douglas-fir stands aged

20 to 60 years. The underlying assumption for Phase II is that the land area lost to Douglas-fir volume production because of a single sprout clump of bigleaf maple can be determined by assessing the wood volume lost at varying distances from the center of a clump.

Bob Wagner and Tim Harrington sampled sprout clumps of bigleaf maple in five Douglas-fir stands on cooperators' lands in Oregon and Washington. The stands were all site class II (Douglas-fir, 50-year basis) and ranged from 22 to 61 years old. Each of the sprout clumps selected for sampling was relatively isolated in pure Douglas-fir stands. Transects extending outward from the center of each clump were established. Variable-radius plots were systematically spaced along each transect to determine the standing volume of Douglas-fir at each distance from the clump.

Data analysis during the coming year will seek to quantify the relation between wood volume and distance from the clump center and thereby determine the effective area lost to Douglas-fir production from clumps of various ages. Preliminary analysis of Douglas-fir basal areas indicates that the "hole" created by sprout clumps of bigleaf maple in Douglas-fir stands 20 to 35 years old is readily apparent. As a stand matures, however, it becomes more difficult to quantify the wood volume loss created by a single clump. This difficulty apparently results from (1) the allocation of wood volume to fewer trees as the stand matures, (2) the development of "holes" of similar size in an adjacent pure stand, and (3) the suppression of the bigleaf maple clumps by adjacent Douglas-fir trees.

Efforts during the coming year will be directed at using data from Phases I and II to estimate the economic threshold for controlling single clumps or groups of clumps on a per-acre basis.

Predicting How Interspecific Competition Affects Growth and Yield of Douglas-fir

In 1987, the CRAFTS Cooperative, the COPE research program, and the Washington Department of Natural Resources provided funds to develop a biomathematical model capable of simulating the growth of young (1- to 20-year-old) Douglas-fir plantations as a function of site factors, tree and stand characteristics, and level of interspecific competition. The study plan outlined a 3-year strategy to produce the model. Tasks for the first year (1987-1988) include a review of the literature and the formation of a conceptual model--a series of mathematical equations that describe the development of Douglas-fir trees and competing vegetation. Tasks to be completed in subsequent years include the construction of a database, fitting the model's equations to data, and model verification and validation. Dan Opalach is the project coordinator for this study. An advisory subcommittee consisting of about 20 experts was formed to provide Dan with guidance and suggestions on model development.

The 1987-1988 tasks are well underway. A report summarizing relevant literature was prepared for the Subcommittee and discussed during a meeting held in February 1988. Also discussed at that meeting was a conceptual model that predicts the development of individual Douglas-fir trees and competing vegetation on a 1/300-acre plot. This conceptual model will be refined until it can adequately describe the developmental patterns typically observed in young Douglas-fir plantations.

The approach employed in developing the conceptual model emphasizes the use of equations and parameters that are biologically interpretable. The strengths and weaknesses of the resulting equations can be discussed and debated by a wide range of researchers including ecologists, silviculturalists, and biometricians.

Formation of the conceptual model has proceeded in conjunction with the development of a simulation model to aid in projecting shrub and hardwood development in young Douglas-fir plantations on the Siuslaw National Forest. (The latter model was developed by Dan Opalach, Bob Wagner, Bruce Maxwell, and Jimmy Dukes.) Output from this simulator is shown in Figure 5.

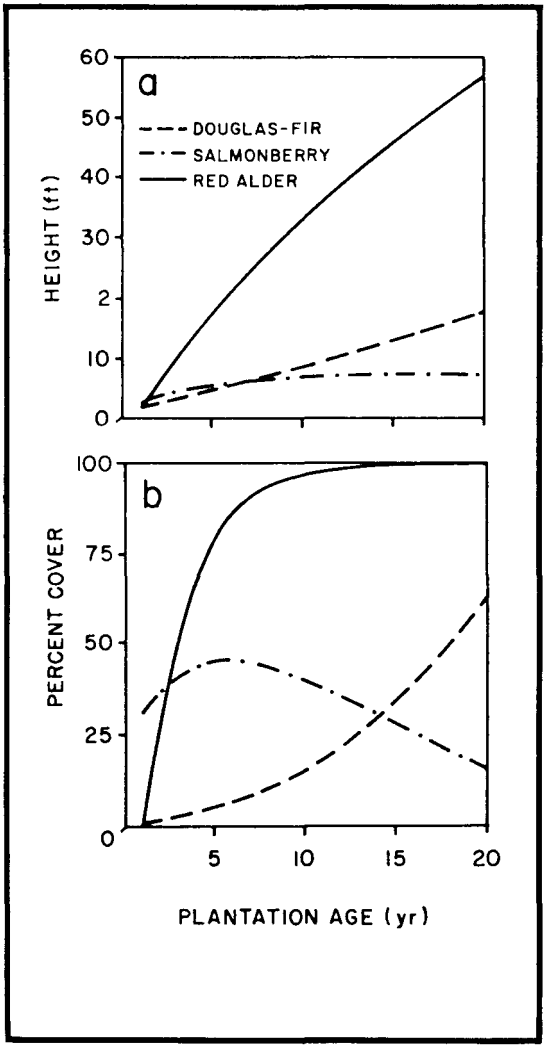

FIGURE 5.--Simulated (a) height development of Douglas-fir subject to competition from red alder and salmonberry and (b) cover development by these three species.

Research plans for the remainder of 1988 call for the addition of diameter growth and survivor functions for each tree species (i.e., Douglas-fir and red alder) included in the conceptual model. The conceptual model will also be expanded so that it simulates the growth of a stand of individual trees. When these tasks are completed, a CRAFTS Technical Report will be written that summarizes the available literature and the development of the conceptual model.

A Computerized System for Vegetation Management Prescriptions

This year CRAFTS personnel proposed a plan to develop a computerized system that can assist forest managers in deciding on vegetation management treatments around the region. Under the plan, new microcomputer technology will be used to develop an information base and computer program that will optimize selection of appropriate vegetation management treatments. When completed, this program will assist foresters with the complex task of evaluating many possible site-preparation and conifer-release treatments on the basis of the species composition of an area, documented treatment efficacy, and current treatment costs. Output from the program will allow users to rank and evaluate the most cost-effective treatments.

Separate programs will be developed for (1) the deciduous brush type in Oregon and Washington, (2) the mixed sclerophyll brush type in southwestern Oregon and northern California, and (3) the herbaceous vegetation complex. Users will be able to select among site preparation or release treatments in each vegetation type according to potential injury to planted conifers. Individual stem and stump treatments will also be developed for the two brush types. Users will have the opportunity to modify the data base of the program to include new information that becomes available or

modify that base to conform to local experience and expertise.

This project will also provide three additional benefits: (1) a means to consolidate and continually update available information on the efficacy of herbicide and manual treatments around the Pacific Northwest, (2) a training tool for foresters to develop and improve their skills in prescribing vegetation management treatments, and (3) a subroutine on vegetation treatments that can eventually be interfaced with the diagnostic model now being developed in the Cooperative. Funding for this project has been provided by the administration of the OSU College of Forestry. A working version of the computerized system is currently proposed for completion in 1989.

ADAPTIVE RESEARCH

Adaptive studies are designed to explore new approaches to managing forest vegetation or to improve existing ones. Usually funded from outside sources, these studies have direct management implications of interest to the Cooperative membership. Members participate at their discretion through the donation of land, labor, or facilities. Examples of such studies conducted by CRAFTS follow.

Interspecific Competition Index for the Siuslaw National Forest

In an effort to provide quantitative techniques for deciding on vegetation management in young Douglas-fir plantations, Bob Wagner and Steve Radosevich are continuing development of an interspecific competition index for use on the Siuslaw National Forest. The study has three objectives: (1) develop a biologically meaningful competition index for measuring nonconiferous vegetation, (2) determine the quantitative

relationship between the competition index and Douglas-fir survival and growth, and (3) develop a means to predict future index values on the basis of the current condition of vegetation in young plantations.

The study is divided into two phases. Phase I utilized plots from two site-preparation experiments on the Siuslaw National Forest to develop preliminary models for meeting objectives 1 and 2. Results from this portion of Phase I were reported last year. Also included in Phase I is the development under objective 3 of preliminary growth models for the most abundant nonconiferous woody species. Phase II involves more controlled experiments with Douglas-fir, salmonberry, and herbaceous vegetation to test and refine the models designed to meet objectives 1 and 2.

Model for predicting future values of the competition index.--Substantial progress was made this year toward developing a way to predict future index values in young Douglas-fir plantations. A computerized simulation model for the most abundant nonconiferous woody species (salmonberry, thimbleberry, red alder, and vine maple) in young Douglas-fir plantations on the Siuslaw National Forest was begun. The model, which was developed by Dan Opalach, Bob Wagner, Bruce Maxwell, and Jimmy Dukes, predicts development of these species for up to 20 years from data on their current height and percentage of cover. The model is based on empirically and theoretically derived equations describing the height growth, cover development, and competitive interactions of these species. Projections of future index values are based on 1/300-acre plots centered around a planted Douglas-fir seedling in the Oregon Coast Range. The effects of the nonconiferous woody species on the height growth of Douglas-fir were known from Phase I of this study.

When the project is completed, foresters can enter the current height and percentage of cover for nonconiferous woody species in young plantations and then simulate the probable course of stand development. With these data, they can then evaluate the need for and likely effect of competition-release treatments in young Douglas-fir plantations. The theoretical foundation for this model was developed in conjunction with Dan Opalach's diagnostic model.

Influence of salmonberry and herbaceous vegetation on Douglas-fir growth in the Oregon Coast Range.-- Phase II of the study is directed at using controlled experiments with newly planted Douglas-fir seedlings to test and refine the preliminary models developed from Phase I. Four sites were established in 1985 on north and south slopes in the *Picea sitchensis* and *Tsuga heterophylla* Zones on the Siuslaw National Forest. On each site, five levels of salmonberry recovery (100, 75, 50, 25, and 0 percent) are being maintained. In addition, 50 and 100 percent of the herbaceous vegetation is removed from plots where all salmonberry recovery has been prevented.

Douglas-fir growth and survival, soil water depletion, and light attenuation under each of the treatments have been recorded for the last three growing seasons. Douglas-fir basal area has responded most sensitively to the level of vegetation removal (Figure 6). Even though many of the seedlings have been severely overtopped in some plots by dense salmonberry, most of the observed growth increases have been associated with the removal of herbaceous vegetation. The increase in basal area is closely correlated with the pattern of soil water depletion throughout the growing season (Figure 7). An interesting finding is that the largest increases in basal area after removal of herbaceous vegetation have been on the wettest sites in the *Picea sitchensis* Zone. This pattern suggests

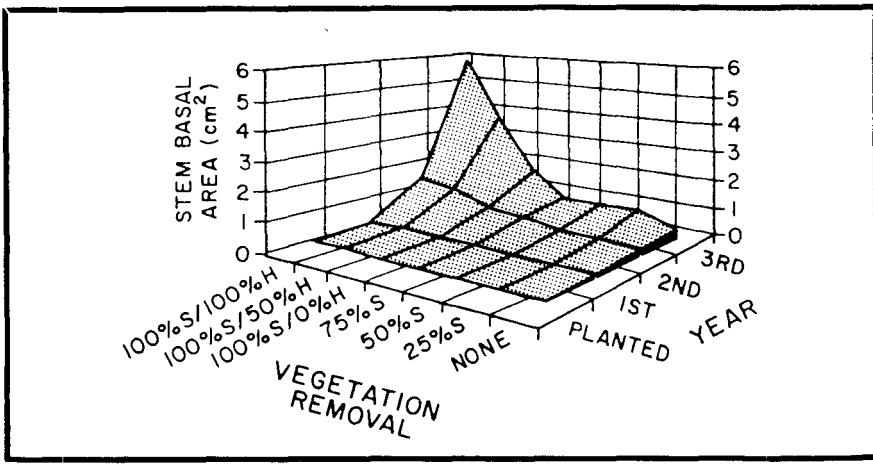

FIGURE 6.--Stem basal area of Douglas-fir seedlings 1, 2, and 3 years after planting at 7 levels of shrub (S) and herbaceous (H) vegetation removal. The site is located on a south aspect in the *Tsuga heterophylla* Zone on the Siuslaw National Forest.

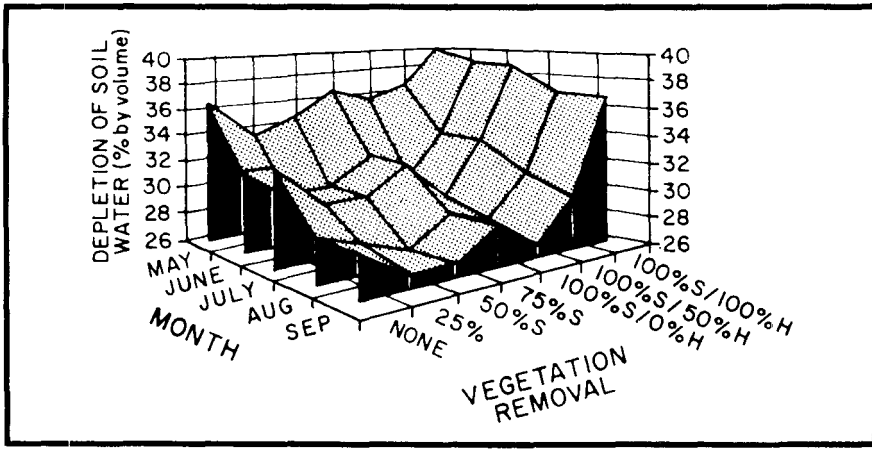

FIGURE 7.--Depletion of soil water content (% by volume) at a depth of 30 cm throughout the 1986 growing season when 7 levels of shrub (S) and herbaceous (H) vegetation were removed. Soil water was measured with a neutron probe. The site is located on a south aspect in the *Tsuga heterophylla* Zone on the Siuslaw National Forest.

that Douglas-fir seedlings are more sensitive to moisture stress than previously assumed and that soil nutrients are an important factor in control of herbaceous vegetation.

More detailed analysis of the data from the first 3 years of these experiments is scheduled for the coming year.

Douglas-fir/Red Alder Replacement Series

Interactions between Douglas-fir and red alder are being studied in a CRAFTS special project directed by Steve Radosevich and Dave Hibbs. This project compares differences in the growth, biomass allocation, and resource requirements of Douglas-fir and red alder in mixed and pure stands. Tim Harrington and Barbara Yoder are coordinating the various phases of this project. Preliminary comparisons of seedling biomass 1 through 3 years after planting suggest that aboveground allocation is similar for the two species--about 68 percent. However, it appears that Douglas-fir allocates more of its aboveground biomass to foliage (44 percent) than does red alder (31 percent).

One aspect of the project concerns how stand composition of Douglas-fir and red alder affects total nutrient pools. Baseline comparisons of large woody debris (>7.5 cm in diameter) in harvested areas and in adjacent undisturbed stands reveal some striking differences after site preparation. On the H.J. Andrews Experimental Forest in the Oregon Cascade Range, large woody debris averaged only 4.66 kg/m^2 after slash was yarded and the test site was broadcast burned, whereas it averaged 74.01 kg/m^2 in an adjacent old-growth stand. Similarly, at Cascade Head in the Oregon Coast Range, large woody debris averaged only 3.71 kg/m^2 after slash was yarded and the site was broadcast burned, while it averaged 13.49 kg/m^2 in the

adjacent 90-year-old stand of western hemlock and Sitka spruce.

BASIC RESEARCH

Basic studies explore fundamental principles important to the science of vegetation management. They provide the basis for innovative technology and, ultimately, better management. They also trigger future adaptive and applied research. Basic studies are usually conducted by graduate students, often Ph.D. candidates. Funding for such projects is always from sources outside the Cooperative, although cooperator participation is encouraged.

Basic research projects conducted by graduate students associated with CRAFTS are described below. Although often fundamental in nature, these studies provide the Cooperative with information on the mechanisms of species interaction.

Pamela Cooke (M.S.): The Role of Density and Proportion in Allometric Equations for Douglas-fir and Red Alder Seedlings

Allometric equations for 3-year-old Douglas-fir and red alder seedlings were developed. Component biomass of Douglas-fir and red alder was best predicted by stem diameter, total height, and crown width. Density was a significant variable for predicting leaf biomass and total biomass of Douglas-fir. The percentage of cover for weed species surrounding the sample trees was a significant variable for predicting root biomass. Total biomass of red alder was correlated with species proportion, indicating that red alder biomass was higher when sample trees were surrounded by a larger number of red alder than of Douglas-fir. Root nodules of red alder also were significantly correlated with the percentage of cover for annual species surrounding sample trees.

K. David Coates (M.S.): Effects of Shrubs and Herbs on Conifer Regeneration and Microclimate in the *Rhododendron-Vaccinium-Menziesia* community of South-Central British Columbia

A field study was established to determine the impact of interfering vegetation on survival and growth of Engelmann spruce and lodgepole pine in the high-elevation Engelmann Spruce-Subalpine Fir (ESSF) Zone of south-central British Columbia. The study examined (1) the influence of varying amounts of shrubs and herbs on microclimate and on performance of planted seedlings, (2) relationships between various measures of vegetation interference and growth of conifer seedlings, and (3) the response of six major shrub and herb species to manual cutting and mechanical scarification.

Conifer diameter was the growth measure most responsive to levels of interference. In the absence of interfering vegetation, mean diameters of spruce and pine were 21.3 percent and 27.5 percent greater, respectively, than those of seedlings in the undisturbed brush. The relationship between growth of individual spruce and pine and various measures of vegetation interference was always negative. A maximum of 25 percent of the variation in seedling growth was explained by measures of interference. Large variance in seedling growth at low levels of interference suggests that either microsite variability or genotype differences constrain seedling performance even in the absence of interference.

Samuel S. Chan (Ph.D.): Effects of Light and Soil Moisture Availability on Growth of Douglas-fir and Red Alder Saplings

A study of the interaction between resource availability and growth of red alder and Douglas-fir

saplings is nearly completed. The study is designed to (1) examine and compare the relationships between Douglas-fir and red alder morphology, carbon allocation, and physiology in response to light and soil moisture availability and (2) develop allometric predictors of stress responses to limitations in environmental resources.

Results indicate that allocation patterns and priorities in red alder are primarily driven by soil moisture availability, whereas the primary mechanism driving Douglas-fir allocation is light availability. These trends in morphology, physiology, and carbon allocation suggest that differences in growth and survival strategies are strongly mediated by resource availability. The patterns of sensitivity and responses of Douglas-fir and red alder to the light and water environment also suggest potential opportunities to manipulate the resource environment to achieve management goals.

J.H. Dukes, Jr (Ph.D.): Gas-Exchange Characteristics of Douglas-fir and Red Alder

The effects of species proportion and total plant density on the relationship of net photosynthesis to light intensity was studied in an addition-series experiment. The same relationships with individuals of both species grown free of competition but with different levels of light and soil moisture availability were also determined.

Light-saturation curves were determined in a controlled environment on shoots from the top whorl of Douglas-fir and from dominant branches of red alder. The response of net photosynthesis to light intensity differed between species and among the treatments. The photosynthetic response of Douglas-fir to irradiance during growth was similar to that of a plant adapted to full sunlight but having the capacity to acclimate to shade. In contrast, the gas-exchange characteristics of red

alder were typical of a plant intolerant of shading. Douglas-fir responded to shading by changing both leaf arrangement on the shoot and gas-exchange characteristics of the leaf. The leaves of shade-grown Douglas-fir were oriented horizontally, whereas those of Douglas-fir grown in the open were arranged in a spiral around the shoot.

Douglas-fir has been observed to survive for many years under a red alder canopy. That the shoots acclimate to more efficient carbon fixation in shaded conditions may be a primary mechanism by which Douglas-fir survives under an alder canopy.

Tim Harrington (Ph.D.): Mechanisms of Competition Between Tanoak and Douglas-fir

In 1983, various levels of tanoak competition were created in two Douglas-fir plantations in southwestern Oregon as part of the F.I.R. research program. One objective of the research was to develop descriptive growth models for each of the two species at the various levels of competition. Tanoak competition was found to reduce height growth of Douglas-fir in two ways: (1) by limiting the number of stem units produced within the terminal bud during a given growing season, and (2) by limiting the period of active shoot elongation. Bud diameter was found to be a good indicator ($r^2 = 0.62$) of the number of stem units available for elongation in a given growing season.

Measurements of Douglas-fir photosynthesis with a portable infrared gas analyzer revealed pronounced differences in the rate and periodicity of carbon assimilation. In the dry year of 1987, photosynthesis of Douglas-fir growing free of tanoak and shrub and herbaceous competition was only slightly reduced as a result of summer drought. Beginning in July and extending through November, Douglas-fir growing with tanoak but receiving full sun underwent drought-imposed reductions in

photosynthesis rate. Douglas-fir that were fully overtopped by tanoak had extremely low rates (often zero or negative) of photosynthesis throughout most of the year.

Bruce Maxwell (Ph.D.): Growth and Demographics of Salmonberry and Thimbleberry

Density gradients of salmonberry and thimbleberry were planted at two sites in the Coast Range to assess demographic and biomass response to intraspecific density. Separate plants of each species were grown without competition and harvested monthly to determine maximum growth within seasons and over two seasons. Growth from seed (seedlings) and from basal stem cuttings (sprouts) was also compared.

Growth analysis conducted on plants growing alone indicated that, at the end of one season, salmonberry and thimbleberry grown from cuttings were 200 to 1,000 times larger than plants grown from seed. After two seasons, however, sprouts from cuttings were only twice as large as seedlings. Absolute growth rates were significantly greater for sprouts than for seedlings. Relative growth rates, however, were often greater for seedlings than for sprouts, chiefly because seedling leaf area ratios were large. Thimbleberry plants grown from cuttings allocate a greater proportion of biomass to rhizomes and less to the root crown than do seedlings of the same species. Salmonberry grown from cuttings allocate a larger proportion of biomass to the root crown and less to rhizomes than do thimbleberry. In both species, there was significantly lower production of basal buds on seedlings than on sprouts. These attributes coupled with low germination rates and low seedling survival suggest that salmonberry and thimbleberry populations are not likely to become established from seed on clearcuts in the central Coast Range.

Laura J. Shainsky (Ph.D.): Competitive Interactions Between Douglas-fir and Red Alder Seedlings

Competitive interactions between Douglas-fir and red alder seedlings were investigated in a highly controlled experiment consisting of a two-species density gradient (addition series). Tree size, canopy architecture, light availability, soil moisture depletion, and leaf water potential were assessed as functions of competition regime. For both species, tree size declined in response to red alder density. Douglas-fir density affected performance of both species as well. The effect of each species density on individual tree performance was summed and found to equal whole-stand properties that influenced the light environment. Increasing red alder density caused reduced light availability to understory Douglas-fir. However, as density of understory Douglas-fir increased, red alder leaf area declined, permitting increased availability of light in the understory. Soil moisture depletion early in the growing season by both species created a stressful soil moisture environment that affected both species' leaf water potentials.

Suzanne Simard (M.S.): Competition Between Sitka Alder and Lodgepole Pine

Lodgepole pine is an important commercial tree species in the Kamloops Forest Region of British Columbia. Sitka alder dominates many of the moist sites unsuccessfully regenerated by lodgepole pine in the Montane Spruce Zone. Sitka alder may benefit lodgepole pine by increasing the nitrogen capital of forest soils, but the community may also suppress pine by competing for light, moisture, or other resources. The objective of this study is to investigate competition between planted lodgepole pine seedlings and a shrub community dominated by varying densities of Sitka alder and associated herbs. Monitoring the availability of environmental

resources at various levels of competition will enable the competition process itself to be better understood.

AUXILIARY RESEARCH

In addition to the three types of research described earlier, CRAFTS also encourages research by other scientists. In this way, information is made available on topics of interest to the cooperators but beyond the scope of the organization itself. An example of such research is screening trials of new herbicides for forestry use.

Near Hoskins in the Oregon Coast Range, the efficacy of several chemicals for site preparation was tested in late June by Mike Newton and associates. Applications of 2,4-D (2 lb/acre), triclopyr ester (1.5 lb/acre), imazapyr (0.5 lb/acre) plus glyphosate (1 qt/acre), imazapyr (0.5 lb/acre), and glyphosate (2 and 3 qt/acre) resulted in almost 100 percent mortality of red alder. On salmonberry, metsulfuron (0.5 oz/acre), imazapyr, and glyphosate were the most effective treatments. Glyphosate (2 and 3 qt/acre) provided the best control of vine maple. 2,4-D, triclopyr ester, metsulfuron, imazapyr, and glyphosate were excellent in controlling hazel.

Screening trials of several chemicals to control herbaceous weeds were begun in March 1986 near Arago on the south coast of Oregon. After the first season, plots treated with sulfometuron (2 oz/acre), sulfometuron (2 oz/acre) plus 2,4-D (2 lb/acre), sulfometuron (2 oz/acre) plus clopyralid (0.25 and 0.5 lb/acre), or clopyralid (0.5 lb/acre) plus atrazine and dalapon (3 lb/acre each) had less than 15 percent vegetative cover, whereas the untreated plots had 94 percent cover. Plots treated with 2,4-D and clopyralid had less than 4 percent forb cover, but their grass cover was over 70 percent.

Screening trials of herbicides for conifer release were conducted in the Coast Range. 2,4-D and sulfometuron, alone and in mixtures, were applied in late April and early May to stands where vegetation competed with Douglas-fir seedlings. 2,4-D was effective on red alder and elderberry but less effective on thimbleberry, salmonberry, vine maple, cherry, and herbaceous plants. Sulfometuron was effective on thimbleberry, salmonberry, cherry (May), and some of the herbaceous plants (primarily velvetgrass), but was ineffective on red alder. Herbicide mixtures gave good results on all shrub species except vine maple. Injury to Douglas-fir was minor; it was primarily caused by 2,4-D applications in May.

TECHNOLOGY TRANSFER

Technology transfer by CRAFTS personnel is directed at communicating information gained through research to foresters and forest researchers around the region. Research is communicated primarily through presentations and publications.

CRAFTS Technical Reports

CRAFTS Technical Reports are prepared so that the CRAFTS staff can rapidly communicate interim and completed results from Cooperative-sponsored studies. Five reports were delivered to the Policy Committee, the Technical Committee, and Cooperator field staff during 1987-88:

- Correlations between overtopping vegetation and development of Douglas-fir saplings in the Oregon Coast Range. S.S. Chan and J.D. Walstad.
- Thresholds of survival and growth of ponderosa pine seedlings competing with woody and herbaceous vegetation. R.G. Wagner, T.P. Petersen, D.W. Ross, and S.R. Radosevich.

- Competition thresholds and determining the need for vegetation treatments in young forest plantations. R.G. Wagner.
- Methods to study interactions among crops and weeds. S.R. Radosevich.
- Factors influencing the delivery and effectiveness of triclopyr in the control of bigleaf maple sprout clumps. R.G. Wagner.

CRAFTS Field Tour

After the October meeting of the Technical Committee, CRAFTS personnel conducted a one-day field tour of research areas and operational programs involving management of herbaceous vegetation in the Oregon Coast Range. Over 40 people from around the region attended this very successful tour. Stops included sites of studies on competition between Douglas-fir and red alder, the effects on Douglas-fir of weed control and protection against animal damage, control of herbaceous weeds, interactions between plug seedlings and triazine herbicides, and development of an interspecific competition index, as well as sites devoted to an industrial program on controlling herbaceous weeds and a Forest Service program on forage seeding and sheep grazing.

Presentations by CRAFTS Personnel at Meetings

The CRAFTS staff made the following presentations at the request of Cooperators in meetings, conferences, and shortcourses during 1987-88:

- Development of an interspecific competition index on the Siuslaw National Forest. R.G. Wagner. Siuslaw National Forest Silviculture Workshop, Cottage Grove, Oregon. May 1987.
- Effects of competing vegetation on Douglas-fir growth in the Oregon and Washington Coast Range. T.B. Harrington. Oregon Department of Forestry,

Western District Annual Reforestation Conference, Corvallis. July 1987.

- Treatment prescriptions for controlling bigleaf maple sprout clumps. R.G. Wagner. Oregon Department of Forestry, Western District Annual Reforestation Conference, Corvallis. July 1987.
- Advances in forest vegetation management research from the CRAFTS Cooperative. R.G. Wagner. Weyerhaeuser Company Spray Effectiveness Meeting, Springfield, Oregon. September 1987.
- How competitive stress affects Douglas-fir growth. T.B. Harrington. Weyerhaeuser Company Meeting on Spray Effectiveness, Springfield, Oregon. September 1987.
- The effects of woody and herbaceous vegetation on conifer survival and growth. R.G. Wagner. Willamette Industries Vegetation Management Meeting, Albany, Oregon. November 1987.
- Effects of competition on Douglas-fir morphology and physiology. T.B. Harrington. Washington Department of Natural Resources, Pesticide Recertification Course. Fife, Washington. April 1988.
- Introduction and overview of the CRAFTS Cooperative. S.R. Radosevich. Washington Department of Natural Resources, Pesticide Recertification Course. Fife, Washington. April 1988.
- Principles of plant competition. S.R. Radosevich. Washington Department of Natural Resources, Pesticide Recertification Course. Fife, Washington. April 1988.
- Siuslaw National Forest competition index study. R.G. Wagner. Washington Department of Natural Resources, Pesticide Recertification Course. Fife, Washington. April 1988.
- Thresholds of interspecific competition for young conifers and evaluating the need for vegetation management treatments. R.G. Wagner. Pesticide Recertification Course, Washington Department of Natural Resources, Fife, Washington. April 1988.

In addition, CRAFTS staff made the following presentations at symposia and scientific meetings:

- Meeting the biological requirements of conifer seedlings during site preparation. R.G. Wagner. Reforestation Planning and Cost Control Shortcourse, College of Forestry, Oregon State University, Corvallis. September 1987.
- Benefits of physiology research to plantation establishment: vegetation management. S.R. Radosevich, T.B. Harrington, and S.P. King. Invited presentation. Society of American Foresters Annual Meeting, Minneapolis, Minnesota. October 1987.
- An overview of the CRAFTS program: cooperative research in forest vegetation management. T.B. Harrington. Forest Vegetation Management Conference, Redding, California. November 1987.
- Diameter distribution growth model for Douglas-fir stands. D. Opalach. Regional Forest Nutrition Research Project, Annual Liaison Committee Meetings, Seattle, Washington. January 1988.
- Competition thresholds and determining the need for vegetation treatments in young forest plantations. R.G. Wagner. Forest Vegetation Management Workshop. Department of Forest Science, College of Forestry, Oregon State University, Corvallis. January 1988.
- An introduction to forest vegetation management tools and techniques. R.G. Wagner. Forest Vegetation Management Workshop, Forestry Extension, Oregon State University, Corvallis. January 1988.
- Triclopyr dose-response curves for control of bigleaf maple sprout clumps. R.G. Wagner. Forest Vegetation Management Workshop, Forestry Extension, Oregon State University, Corvallis. January 1988.
- Physiology and carbon allocation of Douglas-fir and red alder saplings in response to light and water availability. S. Chan and S.R. Radosevich. Proceedings, Vegetation Competition and Responses:

Processes, Results and Management Implications. Vegetation Management Workshop, Vancouver, British Columbia, Canada. February 1988.

- Physiological, morphological, and carbon allocation strategies of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) and red alder (*Alnus rubra* Bong.) under varied light and soil moisture levels: third-year results. S.S. Chan, S.R. Radosevich, and J.D. Walstad. Weed Science Society of America Annual Meeting, Las Vegas, Nevada. February 1988.
- Projecting site occupancy of bigleaf maple sprout clumps in Douglas-fir plantations of western Oregon and Washington. T.B. Harrington, R.G. Wagner, and S.R. Radosevich. Weed Science Society of America Annual Meeting, Las Vegas, Nevada. February 1988.
- Competition within two species with clonal growth habits--salmonberry (*Rubus spectabilis* Pursh) and thimbleberry (*Rubus parviflorus* Nutt.)--in clearcuts in the Coast Range of western Oregon. B.D. Maxwell and S.R. Radosevich. Weed Science Society of America Annual Meeting, Las Vegas, Nevada. February 1988.
- A population modeling approach to vegetation management research with reference to *Rubus spectabilis* and *Rubus parviflorus*. B. Maxwell and S.R. Radosevich. Proceedings, Vegetation Competition and Responses: Processes, Results and Management Implications. Vegetation Management Workshop, Vancouver, British Columbia, Canada. February 1988.
- A diagnostic tool for predicting the effects of interspecific competition on growth and yield of young Douglas-fir stands. D. Opalach. Fernhopper Day technical session presentation, Oregon State University, Corvallis. February 1988.
- Douglas-fir and red alder seedling competition in mixed and monoculture stands. L.J. Shainsky and S.R. Radosevich. Proceedings, Vegetation Competition and Responses: Processes, Results and Management Implications. Vegetation Management

Workshop, Vancouver, British Columbia, Canada. February 1988.

- Mechanisms of competition between two tree species. L.J. Shainsky and S.R. Radosevich. Weed Science Society of America Annual Meeting, Las Vegas, Nevada. February 1988.
- Comparison of Nelder and replacement series designs for examining intra- and inter-specific competition among annual crops and weeds. R.G. Wagner, S.R. Radosevich, M.L. Roush, B.D. Maxwell, and T.D. Petersen. Weed Science Society of America Annual Meeting, Las Vegas, Nevada. February 1988.
- Interspecific competition indices for vegetation management decisions in young Douglas-fir stands. Invited presentation. R.G. Wagner and S.R. Radosevich. Proceedings, Vegetation Competition and Responses: Processes, Results and Management Implications. Vegetation Management Workshop, Vancouver, British Columbia, Canada. February 1988.
- Meeting the biological requirements of conifer seedings during site preparation. R.G. Wagner. Reforestation Planning and Cost Control Shortcourse, College of Forestry, Oregon State University, Corvallis. February 1988.
- An overview of CRAFTS research. R.G. Wagner. Vegetation Management Workshop, Vancouver, British Columbia, Canada. February 1988.
- Plant competition and young stand growth models. R.G. Wagner. Fernhopper Day Technical Session, College of Forestry, Oregon State University, Corvallis. February 1988.
- Thresholds of survival and growth for ponderosa pine seedlings (*Pinus ponderosa* Dougl. ex Loud.) under interspecific competition with woody and herbaceous vegetation. R.G. Wagner, T.D. Petersen, D.W. Ross, and S.R. Radosevich. Weed Science Society of America Annual Meeting, Las Vegas, Nevada. February 1988.
- Predicting the effects of tanoak competition on Douglas-fir growth. T.B. Harrington and J.C.

Tappeiner II. Northwest Scientific Association, 61st Annual Meeting, Ashland, Oregon. March 1988.

- Fertilizer responses of Pacific Northwest tree species. D. Opalach. Conference on Improving Forest Fertilization Decision-Making in British Columbia, Vancouver, B.C. March 1988.
- The potential to predict the benefits, costs, and consequences of prescribed burning. S.R. Radosevich. The Burning Decision: A Regional Symposium on Slash. Seattle, Washington. April 1988.
- Allometric relationships of young red alder and Douglas-fir at four sites in western Oregon and Washington. B.J. Yoder, T.B. Harrington, and D.E. Hibbs. Annual Meeting of the American Association for the Advancement of Science, Pacific Division. Corvallis, Oregon. June 1988.

Publications by CRAFTS Personnel

Thirty publications were prepared by CRAFTS personnel during 1987-88. A complete list is presented in Appendix I.

ORGANIZATIONAL ACTIVITIES

CRAFTS committees met five times this year to address various aspects of the Cooperative. The Policy and the Technical Committees met during the year to determine funding levels and review CRAFTS experiments. A newly created Advisory Subcommittee was formed to provide technical guidance on the development of the young stand model. A special Subcommittee on Short-Term Research Projects was organized to determine possible use of upcoming short-term research funds.

Policy Committee

The Policy Committee met in June 1987 on OSU Research Cooperative Policy Day. The Committee

reviewed current research and approved funding levels outlined in the current 5-year plan. The Committee also discussed funding for technology transfer in the Cooperative. Additional topics included development of a diagnostic model to aid in decision-making about vegetation management, coordinating research efforts with the University of Washington's Stand Management Cooperative, and strategies to obtain new members of the Cooperative. Tom Terry (Weyerhaeuser Company) was elected Executive Officer of the Policy Committee for 1987-88. The Committee also recommended that a new 5-year plan to secure funding be developed at least every other year.

Technical Committee

The Technical Committee met in October 1987 and April 1988 to review CRAFTS experimental designs, research results, and other issues involving vegetation management around the region. During 1987-88, the Committee accomplished the following:

- Reviewed a study plan on developing a growth model for sprout clumps of bigleaf maple
- Developed strategies for construction of a young stand model for vegetation management in the Pacific Northwest
- Reviewed Coast Range Release Study
- Reviewed screening trial of treatments for controlling sprout clumps of bigleaf maple
- Reviewed plans for the development of a database for mixtures of Douglas-fir and red alder
- Reviewed guidelines issued by the Department of Environmental Quality and the Oregon Department of Forestry about managing chemical spills in the forest
- Reviewed results of screening trials for forest herbicides
- Reviewed plans of the COPE program for research on vegetation management
- Developed ideas for short-term research projects

Advisory Subcommittee on the Young Stand Model

This Subcommittee is responsible for overseeing the CRAFTS young stand model now being developed by Dan Opalach. The Subcommittee will serve throughout the 3-year development of the model. In February, the Subcommittee discussed and defined the scope of the model, its form, data sources, and linkage with older stand models. Subcommittee meetings will be held periodically in the coming year to direct various aspects of model development. Kelsey Milner (Champion International Corporation) and Bob Wagner co-chair this Subcommittee.

Subcommittee on Short-Term Research Projects

This Subcommittee was formed to develop possible options for the use of short-term research project funds. These funds are scheduled to become available in 1988-89 under the current CRAFTS 5-year plan. At the March meeting, the Subcommittee developed three options for presentation to the Technical Committee, which acted upon their recommendation.

The Cooperative thanks Chairman Gary Blanchard (Starker Forests), Jerry Chetock (Oregon Department of Forestry), and Ron Heninger (Weyerhaeuser Company) for their efforts on this Subcommittee.

APPENDIX I

Publications and Papers Prepared by CRAFTS Personnel (1987-88)

Bare, B.B., and D. Opalach. 1987. Optimizing species composition in uneven-aged forest stands. Forest Science 33:958-970.

Bare, B.B., and D. Opalach. 1987. Using a direct search algorithm to optimize species composition in uneven-aged forest stands. Paper presented at

the IUFRO Forest Growth Modeling and Prediction Conference, August 24-28, 1987, Minneapolis, Minnesota.

Bare, B.B., and D. Opalach. 1988. Determining investment-efficient diameter distributions for uneven-aged northern hardwoods. Forest Science 34:243-249.

Chan, S.S., and J.D. Walstad. 1987. Correlations between overtopping vegetation and development of Douglas-fir saplings in the Oregon Coast Range. Western Journal of Applied Forestry 2:117-119.

Childs, S.W., H.R. Holbo, L.J. Shainsky, and S.R. Radosevich. 1987. Autocorrelation analysis of radiation penetration in Douglas-fir and red alder canopies. *In* Eighth Conference on Biometerology and Agrobiology, Purdue University, West Lafayette, Indiana.

Cole, E.C., M. Newton, and D.E. White. 1988. Efficacy of imazapyr and metsulfuron methyl for site preparation and conifer release in the Oregon Coast Range. Research Note 81. Forest Research Laboratory, Oregon State University, Corvallis, Oregon. 7 p.

Harrington, T.B. 1987. An overview of the CRAFTS program: cooperative research in forest vegetation management. *In* Proceedings, Forest Vegetation Management Conference, Redding, California.

Harrington, T.B., and J.C. Tappeiner II. 1988. Predicting the effects of tanoak competition on Douglas-fir growth. *In* Proceedings, Northwest Scientific Association 61st Annual Meeting, Ashland, Oregon.

Harrington, T.B., R.G. Wagner, and S.R. Radosevich. 1988. Projecting site occupancy by bigleaf maple sprout clumps in Douglas-fir plantations of western Oregon and Washington. Weed Science Society of America Abstracts 28:171.

Hobbs, S.D., and S.R. Radosevich. 1987. Nonchemical control of evergreen hardwoods competition in new conifer plantations. In Symposium proceedings on Multiple-use Management

of Californian Hardwood Resources, R. Martin, ed., San Luis Obispo, California.
Hughes, T.F., C.R. Latt, J.C. Tappeiner II, and M. Newton. 1987. Biomass and leaf-area estimates for varnishleaf ceanothus, deerbrush, and whiteleaf manzanita. Western Journal of Applied Forestry 2:124-128.
Maxwell, B.D., M.V. Wilson, and S.R. Radosevich. A model for studying leafy spurge (*Euphorbia esula*) population dynamics. Weed Technology (in press).
Newton, M. 1987. Concepts and realities of weed control and stand establishment. *In* Proceedings, Weed Control and Reforestation Workshop, O.T. Helgerson, ed., FIR Program, Oregon State University, Corvallis, Oregon.
Newton, M. 1987. Efficacy of alternative methods for dealing with competing vegetation. Proceedings, Forest Vegetation Management, Executive Summary, Oregon State University, Corvallis, Oregon.
Newton, M., and T.D. Petersen. 1987. A scientist's perspective on the use of herbicides. Evergreen 1(6):3-4.
Opalach, D. 1988. Fertilizer responses of Pacific Northwest tree species. Paper presented at the workshop/conference on Improving Forest Fertilization Decision-making in British Columbia, March 2-3, 1988, Vancouver, B.C.
Opalach, D., and L.Heath. 1987. Evaluation of long-term fertilizer response. Paper presented at the IUFRO Forest Growth Modeling and Prediction Conference, August 24-28, 1987, Minneapolis, Minnesota.
Opalach, D., L. Heath, and H.N. Chappell. 1987. Growth response to single and multiple nitrogen fertilizer applications in thinned Douglas-fir stands. RFNRP Report No. 8. University of Washington, Seattle, Washington.
Radosevich, S.R. 1987. Methods of interference study. *In* Weed-crop Interactions. M. Alteri, ed. CRC Press, Boca Raton, Florida (in press).

Radosevich, S.R. 1987. Methods to study competition among crops and weeds. Weed Technology 1:190-198.
Radosevich, S.R. 1988. The potential to predict the benefits, costs, and consequences of prescribed burning. *In* The Burning Decision: A Regional Symposium on Slash, April 1988, Seattle, Washington.
Radosevich, S.R., T.B. Harrington, and S.P. King. 1987. Benefits of physiology research to plantation establishment: vegetation management. *In* Proceedings, Society of American Foresters Annual Meeting, October 1987, Minneapolis, Minnesota.
Wagner, R.G. 1987. Comparison of treatments to control bigleaf maple sprout clumps. FIR Report 9(3).
Wagner, R.G. 1988. Competition thresholds and determining the need for vegetation treatments in young forest plantations. *In* Forest Vegetation Management Workshop Notebook. Department of Forest Science, College of Forestry, Oregon State University, Corvallis, Oregon. 23 p.
Wagner, R.G. 1988. Factors influencing the delivery and effectiveness of triclopyr in the control of bigleaf maple sprout clumps. CRAFTS Technical Report. Forest Research Laboratory, Oregon State University, Corvallis, Oregon. 13 p.
Wagner, R.G., T.D. Petersen, D.W. Ross, and S.R. Radosevich. 1988. Thresholds of survival and growth for ponderosa pine seedlings under interspecific competition with woody and herbaceous vegetation. Weed Science Society of America Abstracts 28:170.
Wagner, R.G., and S.R. Radosevich. 1988. Interspecific competition indices for vegetation management decisions in young Douglas-fir stands. *In* Vegetation Competition and Responses: Processes, Results and Management Implications. Proceedings, 3rd Annual Vegetation Management Workshop, Vancouver, British Columbia (in press).
Wagner, R.G., S.R. Radosevich, M.L. Roush, B.D. Maxwell, and T.D. Petersen. 1988. Comparison of

Nelder and replacement series designs for examining intra- and inter-specific competition among annual crops and weeds. Weed Science Society of America Abstracts 28:160.

Yoder, B.J., T.B. Harrington, and D.E. Hibbs. 1988. Allometric relationships of young red alder and Douglas-fir at four sites in western Oregon and Washington. *In* Annual Meeting of the American Association for the Advancement of Science, Pacific Division, June 1988, Corvallis, Oregon.

APPENDIX II

Financial Support Received in 1987-88

Cooperators	Financial Support
Boise Cascade Corporation	$ 5,500
British Columbia Ministry of Forests	5,500
Bureau of Land Management	5,500
Cavenham Forest Industries	5,500
Champion International Corporation	5,500
International Paper Company	5,500
ITT-Rayonier, Inc.	5,500
Lone Rock Timber Company	2,700
Longview Fibre Company	5,500
MacMillan Bloedel Limited	5,500
Oregon State Department of Forestry	5,500
Simpson Timber Company	5,500
Starker Forests, Inc.	2,750
USDA Forest Service, Pacific Northwest Forest and Range Experiment Station[1]	
Washington Department of Natural Resources	20,500
Weyerhaeuser Company	5,500
Willamette Industries, Inc.	5,500
Subtotal	$ 97,500
Forest Research Laboratory, Oregon State University	111,552
Subtotal	$209,052
Other Sources[2]	
USDA, Siuslaw National Forest[3] (Radosevich and Wagner, 1987)	31,781
USDA, Forest Service NAPIAP Program (Radosevich and Hibbs, 1987)	39,285
USDA, Competitive Grants: Biological Stress[3] (Hibbs and Radosevich, 1986 and 1988)	80,000
USDA Competitive Grants: Forestry[3] (Newton, Cole, and Radosevich, 1986-1991)	134,000
COPE[3] (Walstad and Radosevich, 1987)	27,000
COPE[3] (Radosevich and Newton, 1987-1988)	36,000
Subtotal	$348,066
Total	$557,118

[1] Support given by in-kind contributions.
[2] Leader for project funded shown in parentheses.
[3] Includes university overhead.


Oregon
State
University