



United States
Department of
Agriculture

Forest Service

Pacific Northwest
Research Station

General Technical Report
PNW-GTR-713
May 2007

Large-Scale Silviculture Experiments of Western Oregon and Washington

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Abstract

Poage, Nathan J.; Anderson, Paul D. 2007. Large-scale silviculture experiments of western Oregon and Washington. Gen. Tech. Rep. PNW-GTR-713. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 44 p.

We review 12 large-scale silviculture experiments (LSSEs) in western Washington and Oregon with which the Pacific Northwest Research Station of the USDA Forest Service is substantially involved. We compiled and arrayed information about the LSSEs as a series of matrices in a relational database, which is included on the compact disc published with this report and available online at <http://www.fs.fed.us/pnw/research/lsse>. The LSSEs are both spatially and temporally large scale, with experimental treatment units between 5 and 100 acres and proposed study durations of 20 to 200 years. A defining characteristic of the LSSEs is that a broad range of response variables are measured to characterize the response of forest ecosystems to experimental treatments. We discuss the general value and limitations of the LSSEs and highlight some possible roles that can be played by the LSSEs in addressing management issues emerging at the beginning of the 21st century.

Keywords: Silviculture, large-scale experiment, LSSE, Oregon, Washington, Pacific Northwest.

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Introduction

In this General Technical Report, we review 12 large-scale silviculture experiments (LSSEs) in western Washington and Oregon with which the Pacific Northwest Research Station (PNW) of the USDA Forest Service (USFS) is substantially involved (fig. 1, table 1). (For the purposes of this report, western Oregon and Washington is defined as the part of those states located west of the crest of the Cascade Range.) We expand upon previous overview efforts that have provided general summaries of many of these LSSEs (e.g., Monserud 2002, Peterson and Monserud 2002, Reutebuch et al. 2004). Our goal is to provide forest managers, planners, and scientists with detailed information about each LSSE and to organize this information in such a way as to facilitate comparison among studies.

This report is organized into several sections. We begin by defining the term LSSE and briefly discussing how these 12 LSSEs came to be. We then document the LSSEs, including study locations, goals, objectives, and research questions, treatments, response variables, and publications. All of this information is stored electronically in a series of matrices contained in the compact disc (CD-ROM) included with this report. We conclude by discussing the general value and limitations of the LSSEs and the role they can play in addressing emerging management issues.

What Are Large-Scale Silviculture Experiments?

Large-scale silviculture experiments are silviculture experiments conducted at operational scales. As true manipulative **experiments** (sensu Hurlbert 1984), LSSEs are characterized by such fundamental elements of experimental design as randomization, replication, and unmanipulated, “control” treatments (Monserud 2002). As **large-scale** experiments, the LSSEs reviewed here are designed to be both spatially and temporally large in scale. The size range of individual LSSE experimental units—typically between 5 and 100 acres, with an average area of approximately 25 acres—falls within that of operational-scale management units on public lands in the Pacific Northwest. Operational-scale experimental units permit inferences drawn from the LSSEs to be directly related to management information needs without having to scale up research results from smaller experimental plots. The LSSEs reviewed here are also temporally large in scale, with proposed study durations of 20 to 200 years. As **silviculture** experiments, these LSSEs include at least one experimental treatment that involves thinning or harvesting of trees to develop silvicultural alternatives. (See Helms 1998 for definitions of silviculture, thinning, harvesting, and other forestry terms.) A defining characteristic of LSSEs is that

The size range of individual LSSE experimental units falls within that of operational-scale management units on public lands in the Pacific Northwest.

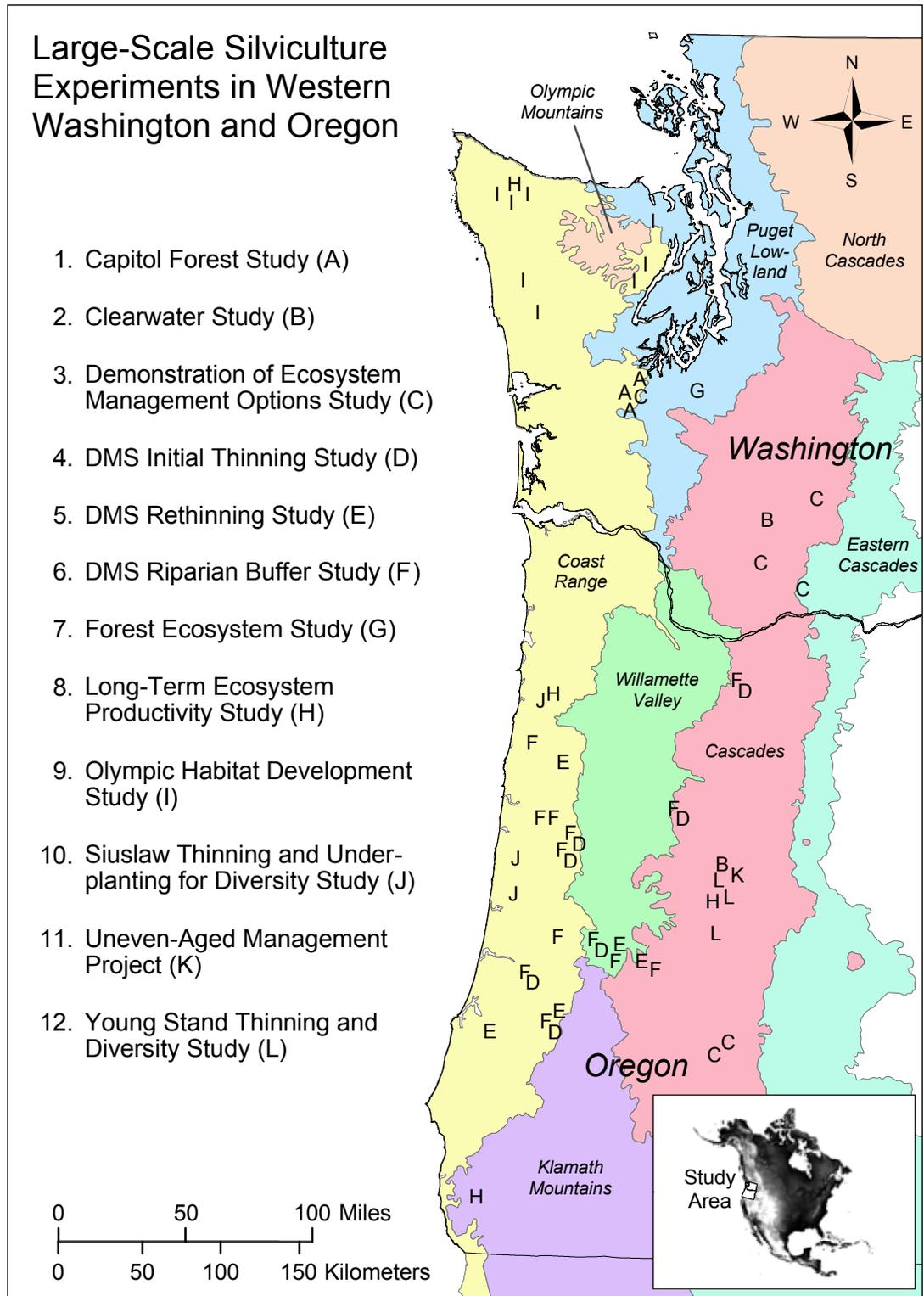


Figure 1—Distribution of geographically distinct locations of large-scale silviculture experiments (LSSEs) in western Oregon and Washington. Multiple copies of a letter indicate multiple installations of a study. Note that each LSSE location shown may include multiple blocks, treatments, and replicates. The LSSE locations are superimposed on Omernik's (1987) level III ecoregions (e.g., Klamath Mountains).

Table 1—Large-scale silviculture experiment codes, names, and appendixes

Study code	Study name	Appendix
CFS	Capital Forest Study	1
CWS	Clearwater Study	2
DEMO	Demonstration of Ecosystem Management Options Study	3
DMS_IT	Density Management Study Initial Thinning Study	4
DMS_RT	Density Management Study Rethinning Study	5
DMS_RB	Density Management Study Riparian Buffer Study	6
FES	Forest Ecosystem Study	7
LTEP	Long-Term Ecosystem Productivity Study	8
OHDS	Olympic Habitat Development Study	9
STUDS	Siuslaw Thinning and Underplanting for Diversity Study	10
UAMP	Uneven-Aged Management Project	11
YSTDS	Young Stand Thinning and Diversity Study	12

Note: See appendixes 1 through 12 for study-specific details such as initial installation years, primary objectives, pretreatment conditions, locations, initial treatments, response variables, study plan citations, and Web sites.

a broad range of response variables (e.g., tree species and size structure, small mammals, woody debris, fungi, soils, microclimate, and social perceptions) are measured to characterize the response of the forest ecosystem to the experimental treatments.

Finally, it should be noted that LSSEs differ from management experiments (MEs), another category of experiments conducted by the USFS. The difference between the two is that LSSEs are undertaken outside of, or in addition to, planned management activities. In contrast, MEs “are well-designed, agency-led administrative studies undertaken as an integral part of management itself and not solely as research projects, as part of an active adaptive management process” (IAC 2006). In a recently implemented ME on the Tongass National Forest, for example, precommercial thinnings planned as part of routine timber stand improvement activities were implemented as a classically designed experiment. As administrative studies, MEs are “usually financed from the Protection and Management appropriation but also may be funded from other specific appropriations, such as the Cooperative Work Fund Forest Service (Knutson-Vandenberg)” (USDA FS 2006). The LSSEs, which are not administrative studies, are funded through a much wider range of sources. Finally, scale is another defining characteristic. The LSSEs are operational in scale by definition, but no size requirement is placed on MEs (although most MEs are conducted by managers using operational resources and operational-sized treatment units).

Three interrelated issues leading up to the NWFP—clearcutting, old growth, and ecosystem management—are all addressed by the LSSEs.

How Did the Large-Scale Silviculture Experiments Come About?

The LSSEs reviewed here were initiated in the 1990s in response to the paradigm shift that occurred in federal forest management in western Oregon and Washington over the past three decades. This paradigm shift, perhaps best symbolized by the implementation of the Northwest Forest Plan (NWFP) in 1994, was characterized by a broadening in management objectives from a wood production focus to a focus on the management of forest ecosystems (USDA and USDI 1994). Three interrelated issues leading up to the NWFP—clearcutting, old growth, and ecosystem management—are all addressed by the LSSEs.

For the 50 years preceding the NWFP, the dominant harvesting and regeneration method employed in the Douglas-fir region was clearcutting (Curtis et al. 1998). However, clearcutting—particularly of old growth—met and continues to meet with great opposition from substantial portions of the public. In many respects, it was clearcutting of old growth—coupled with the growing awareness of the biological and ecological uniqueness of old growth—that led to the NWFP. A primary motivation for undertaking many of the LSSEs was, therefore, to develop alternatives to clearcutting. Correspondingly, a motivation for undertaking many of the LSSEs was to determine whether the development of old-growth forest structure could be accelerated in young managed forests through silvicultural manipulations and treatments.

Ecosystem management, which has been facilitated by the rapidly developing science of landscape ecology, emphasizes scale of structure and process, as well as the importance of spatial context. For silviculturists and other forest managers, the advent of ecosystem management brought several issues to light. There was the recognition that the stand metrics commonly used to assess the effects of silvicultural treatments under the wood production paradigm were inadequate within the context of ecosystem management. Characterization of forest ecosystem responses solely in terms of overstory and understory abundance and composition of tree or woody competitor species was insufficient. Furthermore, the impacts of silvicultural treatments and systems on a broad spectrum of spatially and temporally dynamic biological and physical response variables needed to be evaluated at larger, more operational scales. Small-plot silviculture studies were not adequate to address many of the questions being raised about silvicultural impacts on wildlife, birds, plant communities, and other important ecological and social response variables. The scale of implementation for silvicultural studies needed to be increased in order to encompass the larger scale of spatial and, in some cases, temporal variation associated with ecological response variables of interest.

The implementation of the NWFP in 1994 reflected the paradigm shift that occurred in federal forest management objectives in the 1990s from a single-commodity focus on wood production to a focus on ecosystem management. Although the LSSEs were not directly established by the NWFP, the NWFP did establish the context and—in some cases—provided the resources to initiate these LSSEs. A direct influence of the NWFP on LSSE initiation was evidenced by the 1994 congressional directives for the USFS to demonstrate ecosystem management in western Oregon and Washington. Funding associated with this mandate contributed directly to the implementation of three LSSEs discussed here: the Demonstration of Ecosystem Management Options (DEMO; app. 3) study, the Olympic Habitat Development Study (OHDS; app. 9), and the Young Stand Thinning for Diversity Study (YSTDS; app. 12) (Reutebuch et al. 2004).¹

For many of the LSSE studies, the assignment of federal lands under the NWFP to land-use allocations such as late-successional reserves (LSRs) and riparian reserves, each with correspondingly broad management prescriptions, provided context in shaping the management information needs as well as science questions and objectives. For example, definition of northern spotted owl (*Strix occidentalis caurina*) habitat requirements established a context for management toward development of late-successional forest structure in LSRs. Discussions surrounding the definition of late-successional forest structure to be developed in LSRs, definitions typically based on the habitat requirements of the northern spotted owl, resulted in preliminary criteria for stand characteristics such as snag abundance and quantities of downed coarse wood that have been used explicitly or implicitly as targets in some LSSEs. Similarly, the NWFP also established a context for management of aquatic and riparian resources. The interim guidelines for delineation of riparian buffers and riparian reserves established under the NWFP are explicitly being tested in the one LSSE with a riparian component.

Methods

The amount of raw information associated with each LSSE is enormous. The information we collected about the LSSEs took the form of study plans, publications, and personal communications with scientists and managers associated with the LSSEs. Our challenge in documenting the LSSEs was to organize this information in such a way as to facilitate comparisons among studies. To do this, we identified

¹Cissel, J. 2006. Personal communication. Study coordinator, Eugene District Office, USDI Bureau of Land Management, 2890 Chad Drive, Eugene, OR 97408-7336.

common organizational themes in the mass of raw information. These organizational themes fell into five broad categories: (1) study goals, objectives, and questions; (2) study treatments; (3) response variables measured; (4) research products (e.g., peer-reviewed journal articles); and (5) general background information about each study (e.g., contact information for project personnel, Web sites, study plans, timelines).

We used these organizational themes to array the information we had collected about the LSSEs into 10 matrices (matrices 1 through 3, 4.1 through 4.3, and 5 through 8) or spreadsheets in an Excel² workbook (Microsoft 2001). The organization of the 10 LSSE matrices (available on enclosed CD-ROM) is shown in table 2. Each of the 10 matrices can be linked to the others through one or more common fields. Typically this linking field is the 3- to 6-character LSSE code included in each matrix. The LSSE code generally appears in either the first column or (for purely formatting reasons) the first row in each matrix. Thus, the LSSE matrices form a relational database.

Table 2—Large-scale silviculture experiment matrices and derived tables and figures

Matrix	Table or figure
1. Study overviews	
2. Goals, questions, objectives	
3. Timeline	Table 3
4.1–3. Treatments	
4.1. Background	Table 4
4.2. Reduced	Table 5
4.3. Expanded	Figure 2
5. Geographic coordinates	Figure 1
6. Response variables	Table 6
7. Products	
8. Contacts	

Matrix 1 provides basic background information about each of the LSSEs. In addition to the LSSE codes and LSSE names (columns A and B), matrix 1 contains general descriptions of study locations, Web sites and overview publications, study plan citations, PNW contacts, management contacts, university contacts, whether the study plan was peer reviewed and reconciled, and a brief description of the steering committee (if one exists) for each LSSE.

²The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

Matrix 2 contains **all** stated goals, objectives, and questions contained in the original and revised study plans of each LSSE (full reference for each citation appears in matrix 7). Matrix 3, which is summarized in table 3, illustrates when study plans were published, treatments were implemented, and products were produced at each LSSE. Treatment information is summarized in matrices 4.1 through 4.3.

Table 3—Years in which study plans (P) were published, treatments (T) were implemented, and products (L, for literature) produced

Study	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Capitol Forest Study							P	T	TL	T	PTL	TL	TL	TL	L	
Clearwater Study				PT	T							L		L		
Demonstration of Ecosystem Management Options Study				PT	PTL	PL	L	L	L	L	L	L	L	L	L	
Density Management Study Initial Thinning Study						T	PT	T	TL	TL	L	L	L	L	L	PL
Density Management Study Rethinning Study						T	PT	T	TL	TL	L	L	L	L	L	PL
Density Management Study Riparian Buffer Study						T	PT	T	TL	TL	TL	L	L	L	L	PL
Forest Ecosystem Study	PT	T	T			L	L	L	PL	L	L	L	L	L	L	L
Long-Term Ecosystem Productivity Study	P					T	TL	T		P	L			L	L	
Olympic Habitat Development Study							PT	T	TL	T	TL	TL	T	TL	TL	TL
Siuslaw Thinning and Underplanting for Diversity Study		T	PTL	L		L	L						L		L	
Uneven-Aged Management Project							T	T	T	T	P		L		L	
Young Stand Thinning and Diversity Study				T	T	T	L	L	L	L	L			L	L	

General background information on the treatments applied at each LSSE is contained in matrix 4.1 and table 4. Initial installation year(s) indicates the range of years over which treatments at an LSSE were installed. The relative arrangement of silvicultural treatments across LSSEs is shown in matrix 4.2 and summarized in table 5. Matrix 4.2 (table 5) shows treatments in reduced or summary form. Treatments are sorted into columns based on the relative degree of overstory removal occurring across each treated stand. Matrix 4.3 expands upon the treatment descriptions presented in matrix 4.2 and summarized in table 5 and figure 2. To facilitate linking matrices 4.2 and 4.3, a common treatment numbering scheme was used in both matrices: 1 = no overstory removal (control), 2 = light overstory removal, 3 = moderate overstory removal, 4 = heavy overstory removal, and 5 = complete overstory removal (clearcut), with the letters a through d in matrix 4.3

Table 4—General large-scale silviculture experiment treatment background information

Study	Initial installation	Pretreatment stand age	Planned study duration	Treatment size	Locations	Blocks per location	Treatments per block	Replicates per treatment per block	Total treatments plots	Future treatments planned	Administrative units	Locations per administrative unit
		<i>Years</i>		<i>Acres</i>								
Capitol Forest Study	1998–2004	40–70	>60	18–96	3	1	6	1	18	Y	1	3
Clearwater Study	1994–1995	10–13	One rotation	16	2	1	5	1 or 5	30	Y	2	1
Demonstration of Ecosystem Management Options Study	1994–1995	65–170	Long term	32	6	1	6	1	36	Possible	5	1–2
Density Management Study Initial Thinning	1996–2000	50–70	40–120	30–60	7	1	4	1	28	Y	5	1–2
Density Management Study Rethinning	1996–2000	60–90	40–120	11–99	5	1	2	1	10	Y	4	1–2
Density Management Study Riparian Buffer	1996–2001	50–90	25–40	Various	13	1	2–7	1–4	Various	Y	8	1–2
Forest Ecosystem Study	1991–1993	55–65	>20	32	1	4	4	1	16	Y	1	1
Long-Term Ecosystem Productivity Study	1996–1998	70–100	200	15–20	4	3–4	4–10	1	100	Y	4	1
Olympic Habitat Development Study	1997–2006	35–62	25	13–25	8	1	1–5	1	16	Possible	4	1–3
Siuslaw Thinning and Underplanting for Diversity Study	1992–1993	30–33	25–30	5–8	3	1	4	1	12	Y	3	1
Uneven-Aged Management Project	1997–2000	35–47	200	20–40	1	4	4	1	16	Y	1	1
Young Stand Thinning and Diversity Study	1994–1996	35–45	Undefined	30–90	3	1–2	4	1	16	Y	2	1–2

Table 5—Number of overstory removal treatments by overstory removal class (and nested non-overstory treatments)

Study	No overstory removal (control)	Light overstory removal	Moderate overstory removal	Heavy overstory removal	Complete overstory removal (clearcut)
Capitol Forest Study	1	1	2	1	1
Clearwater Study	1		1	3	
Demonstration of Ecosystem Management Options Study	1	1	2	2	
Density Management Study Initial Thinning	1	1	2		
Density Management Study Rethinning	1		1		
Density Management Study Riparian Buffer	1	1	1	2	
Forest Ecosystem Study	1 (2)		1 (2)		
Long-Term Ecosystem Productivity Study	1		1 (2)		2 (2)
Olympic Habitat Development Study	1		1 (4)		
Siuslaw Thinning and Underplanting for Diversity Study	1	1	1	1	
Uneven-Aged Management Project	1	2		1	
Young Stand Thinning and Diversity Study	1	2		1	

Note: Light overstory removals retained more than two-thirds of the fully stocked basal area, moderate overstory removals retained one- to two-thirds of the fully stocked basal area, and heavy overstory removals retained less than one-third of the fully stocked basal area. The number of non-overstory treatments nested within a single overstory treatment is indicated by the numbers in parentheses. At FES, for example, “den augmentation” (i.e., creation of dens) and “no den augmentation” are two additional treatments nested within the no overstory removal and moderate overstory removal treatments.

indicating variations on a particular overstory removal treatment. The intent of a particular LSSE treatment is described if it was documented in the study plan for the LSSE. The initial overstory removal treatment is described in greater detail.

The latitudes and longitudes in decimal degrees of the approximate geographic centers of geographically distinct treatment blocks are contained in matrix 5. These “coarse-scale” coordinates were used to generate the map of LSSE sites in figure 1 and appendixes 1 through 12. All latitudes and longitudes are given in decimal degrees with the Geodetic Reference System of 1980 and the North American Datum of 1983 used as the spheroid and datum, respectively.

The response variables sampled and the products referring to these response variables are identified in matrix 6 and summarized in table 6. This list of response variables has been compiled from LSSE study plans, written and oral input obtained from LSSE scientists and managers, and previous synthesis publications (e.g., Monserud 2002, Peterson and Monserud 2002).

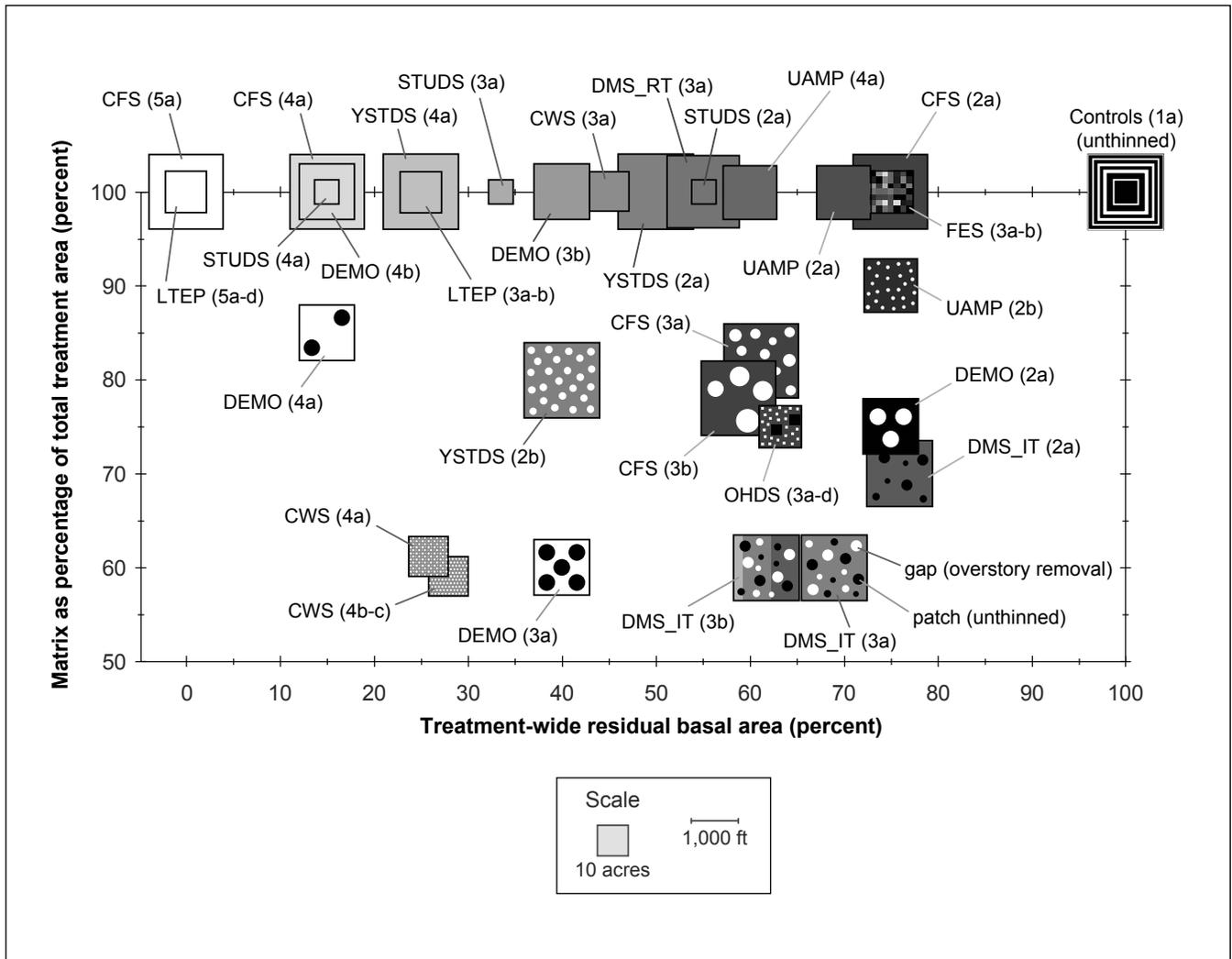


Figure 2—Spatial pattern and scale of initial large-scale silviculture experiment (LSSE) overstory treatments. The x-axis indicates the treatment-wide percentage of fully stocked basal area retained following the initial overstory removal treatment. The range of treatments along the x-axis extends from clearcut treatments (i.e., no basal area retained; e.g., CFS treatment 5a; refer to table 1 for LSSE site codes) to unthinned control treatments (i.e., 100 percent of fully stocked basal area retained). The y-axis indicates the percentage of the total treatment area made up by the matrix of each LSSE treatment; the matrix is the “background” or dominant feature of the treatment-wide spatial pattern. For uniformly thinned stands (e.g., DEMO treatment 3b) and the unthinned controls, the matrix represents 100 percent of the total treatment area. Shading indicates residual overstory density, with lighter shades indicating more open residual canopies. Average treatment scale for each LSSE is indicated by the size of each treatment unit. Overstory removal gaps and patches of leave trees are shown by white and black dots, respectively.

Table 6—General summary of response variables shown in detail in matrix 6

Response variables	CFS ^a	CWS	DEMO	DMS_IT	DMS_RT	DMS_RB	FES	LTEP	OHDS	STUDS	UAMP	YSTDS
Vegetation, over- and midstory	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Vegetation, understory	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Lichens, mosses, and bryophytes	Y	Y	Y	Y		Y		Y	Y	Y	Y	
Mammals, large (e.g., deer)									Y			
Mammals, arboreal			Y				Y		Y			
Mammals, small (e.g., shrew)			Y				Y	Y	Y			Y
Bats			Y						Y			
Birds	Y		Y	Y			Y	Y				Y
Arthropods			Y	Y		Y	Y		Y			
Reptiles and amphibians			Y	Y		Y	Y	Y	Y			
Fish						Y						
Mollusks			Y	Y		Y			Y			
Snags	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y	Y
Woody debris		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Fungi			Y	Y		Y	Y	Y	Y			Y
Soils							Y	Y				Y
Climate		Y						Y				
Microclimate			Y	Y		Y	Y		Y	Y		
Hydrology and geomorphology			Y			Y						
Forest pathology							Y	Y				
Social perceptions	Y		Y					Y				Y
Wood production	Y	Y						Y	Y	Y	Y	Y
Economics	Y	Y								Y		
Operational factors	Y								Y	Y		Y
Roads							Y		Y			
Forest floor	Y	Y	Y	Y	Y	Y		Y	Y	Y	Y	Y

^aSee table 1 for study names.

Product citations are listed in matrix 7. Products include peer-reviewed journal articles, reports, book chapters, conference proceedings, theses, educational videos, and study plans. For some LSSEs, original study plans have been appended to published progress reports or are otherwise available via online Web sites. In other cases, original study plans have been appended to formally published establishment reports and revised study plans (e.g., Cissel et al. 2006 for the Density Management Study (DMS)). Only products with a reasonable probability of being located by readers have been cited in matrix 7. For example, abstracts of posters included in published conference proceedings are cited, but the original poster will not be cited in most cases.

Matrix 8 contains the current contact information (i.e., address, e-mail, telephone) for scientists and managers currently associated with the LSSEs.

We sent the original draft of the LSSE matrices to the principal investigators and management liaisons of each study for review and, where necessary, correction. We reviewed the edited matrices with the principal investigators and management liaisons before compiling the final version of the LSSE matrices, LSSE_matrix.xls. A copy of LSSE_matrix.xls is included in the CD-ROM published with the hardcopy version of this report and is also available online from the LSSE Web site maintained by the PNW (<http://www.fs.fed.us/pnw/research/lse/>, last accessed on February 14, 2007). Updates to the LSSE matrices will be posted on the LSSE Web site as time and funding permit.

To enable readers to gain an overview of the matrices while reading the report without having to continually shift between the hardcopy and electronic media, we have included portions or summaries of most of the LSSE matrices as tables and figures in the printed body of this report. Table 2 identifies which tables and figures correspond to which matrices. Additionally, we created summaries of each study and included them as appendixes at the end of this report (app. 1 through 12).

Results

The LSSEs are located on public forest lands managed by the USFS, USDI Bureau of Land Management (BLM), U.S. Department of Defense, and the Washington State Department of Natural Resources (WADNR) (matrix 1). The majority of LSSEs have study sites confined to single forests. Exceptions to this are the three components of DMS, DEMO, and the Long-Term Ecosystem Productivity study (LTEP; app. 8), which have study sites located at multiple forests. The DEMO study, for example, has sites located on two national forests and one state forest. The LSSEs located on multiple forests, districts, or resource areas require additional administrative effort.

Web sites exist for all of the LSSEs (matrix 1). However, the amount of information available online for each LSSE covers a range of quality and quantity. Given that (1) the earliest initial treatment year for any LSSEs was 1992, (2) treatments were still being installed in 2006 at some LSSEs, and (3) the process of measurement, remeasurement, analysis, and publication is a lengthy one, few if any data are available online for any of the LSSEs. A notable exception to this is DMS, for which some data are publicly available online at <http://ocid.nacse.org/nbii/density/> (last accessed November 21, 2006).

Many of the stated goals, objectives, and questions are quite general in nature (matrix 2). Few are posed in explicitly testable terms. The only two LSSEs with one or more goals or objectives formulated as testable statements are the Forest Ecosystem Study (FES; app. 7) and OHDS. Despite these potential shortcomings, it is clear from the stated goals, objectives, and questions that the three interrelated issues noted in the Introduction as leading up to the NWFP—clearcutting, old growth, and ecosystem management—are all addressed by the LSSEs. For example, all of the LSSEs examine silvicultural alternatives to clearcutting. Over two-thirds of the LSSEs address the question of whether or not the development of late-successional/old-growth (LSOG) forest structure(s) can be accelerated in young managed forests through silvicultural manipulations and treatments. Although the LSOG theme clearly addresses management needs associated with the LSRs established under the NWFP, only two of the LSSEs explicitly define LSOG structural criteria with which to judge relative success or failure. The two LSSEs that explicitly define LSOG structural criteria are the initial thinning component of DMS (DMS_IT; app. 4) and the rethinning component of DMS (DMS_RT; app. 5).

Several of the LSSEs have completed revisions to their original study plans (matrix 3, table 3). Installation of treatments required more than a year at all LSSEs. All LSSEs have generated products, an increasing number of which are journal articles and other peer-reviewed publications.

Also shown in matrix 3 (but not in table 3) are key events such as the listing of the northern spotted owl in 1990 and the convening of the Forest Ecosystem Management Assessment Team in 1993 (FEMAT 1993), which led to the adoption of the NWFP in 1994. In 2003, PNW scientists and managers collaborated in the development of an International Union of Forestry Research Organizations (IUFRO) working group focused on large-scale ecological experiments. A meeting held in Davos, Switzerland, brought together a core group of researchers from North America, Asia, and Europe to examine the role of large-scale experimentation in forest management research (Szaro and Peterson 2004). In August 2004, the scope of this endeavor was expanded through an IUFRO workshop held in

It was evident from these events that the vast majority of operational-scale silviculture studies are being conducted in the Pacific Northwest region of North America.

Portland, Oregon (Peterson and Maguire 2005). It was evident from these events that the vast majority of operational-scale silviculture studies are being conducted in the Pacific Northwest region of North America. It was also evident that there are substantial differences among researchers' concepts of large-scale multidisciplinary research. Whereas the PNW studies focus on large-scale treatment units, many of the European studies are developed around relatively smaller treatment units but address more response variables.

Events such as the IUFRO workshops highlight the potential breadth of information being generated regionally and globally. Although individual studies provide answers to important questions, each has a scope of inference dictated by the particular range of treatments imposed, response variables measured, geographic distribution of replicates, and statistical power associated with its design. When they are arrayed collectively, it is apparent that many of the studies share common questions with more or less common approaches. To maximize the collective value of these efforts requires communication among scientists engaged in these studies and between scientists and managers defining the information needs and objectives underlying the studies. An initial attempt to develop an organized forum for cross-study communication was presented at the 2005 North American Forest Ecology Workshop. A Web-based center of information was proposed to foster communications among scientists with a long-term agenda of facilitating collaboration and promoting synthesis across studies (Puettmann et al. 2005). In April 2006, a 2-day workshop in North Bonneville, Washington, brought together over 35 scientists, management liaisons, and agency administrators to discuss the 12 LSSEs.

Treatments at most LSSEs were installed within a fairly narrow timeframe, generally within a 2- or 3-year period that includes both pretreatment data collection and treatment implementation (matrix 4.1). An exception to this is OHDS, where 10 years were required to install the full set of treatments at the eight OHDS locations on the Olympic Peninsula. At the time of treatment, the majority of LSSE stands were fully stocked, even-aged stands consisting primarily of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco). At most LSSEs, stand ages at the time of initial treatment fell between 25 and 80 years. The Clearwater Study (CWS; app. 2), with a pretreatment range of stand ages of 10 to 13 years, contained the youngest stands treated. Despite the CWS having the youngest pretreatment stand ages, one of the CWS objectives is to “[a]ccelerate the development of characteristics associated with late-successional forests” (Harrington and Carey 1997).

The majority of LSSEs may be viewed as long-term studies (matrix 4.1). Some, such as DMS_IT and the Uneven-Aged Management Project (UAMP; app. 11), have planned study durations in excess of 100 years. It is unknown whether

such an ambitious effort can be sustained financially. However, it is clear that future treatments were envisioned for the majority of LSSEs experiments. For example, Curtis et al. (2004) explicitly noted that subsequent entries would occur on a 15-year cycle in the patch cut and group selection treatments of CFS. This 15-year cycle has subsequently been revised down to a shorter, 10-year cycle.³

The relative spatial scale and geographic extent of each LSSE are captured by the descriptors “administrative unit,” “location,” “blocks,” and “treatments” (matrix 4.1). In this assessment, we consider national forest districts, BLM resource areas, and state forests as administrative units, the coarsest spatial scale. “Location,” reflecting a finer spatial scale than “administrative unit,” indicates a spatially clumped collection of treatment plots within a particular forest district or resource area. For example, DEMO has blocks of treatments on three forests: the Umpqua National Forest in Oregon and the Gifford Pinchot National Forest (GPNF) and Capitol State Forest in Washington. Three blocks of DEMO treatments are located on the GPNF, with one block on each of three GPNF districts, which we consider administrative units. On the GPNF, blocks of treatments only occur at one location within each of the three administrative units (i.e., one block per GPNF district). The two blocks of DEMO treatments on the Umpqua National Forest (UNF), in contrast, occur at two locations on the same administrative unit (i.e., two blocks per UNF district). Blocks identify groups of replicated treatments. Replicates reflect the finest spatial scale. The total number of treatment plots for each LSSE is arrived at by multiplying (assuming a balanced design) locations \times blocks per location \times treatments \times number of replicates (matrix 4.1).

The treatment plots of most LSSEs reflect the variability in slope, elevation, and aspect found in the general area in which each LSSE is located. In other words, treatment plots represent “typical” management units. Because of the experimental nature of LSSEs, however, several LSSEs do not reflect operational constraints. For example, additional effort was involved marking trees for the variable-density thinnings at DMS_IT, FES, and OHDS; even so, the variable-density thinnings were still economical. In other cases, harvesting practices were unique. At the Siuslaw and Underplanting for Diversity Study (STUDS; app. 10), loggers used smaller yarders than those typically used in the Coast Range. Finally, “typical” administrative constraints were relaxed for some LSSEs. For example, the riparian buffer component of DMS (DMS_RB; app. 6) employed riparian buffer width treatments that would not have been permitted ordinarily.

³Marshall, D. 2006. Personal communication. Biometrician, Weyerhaeuser Company WTC 1A5, P.O. Box 9777, Federal Way, WA 98063-9777.

Many treatment regimes or silvicultural prescriptions (each composed of different silvicultural treatments) of the stand-level studies can be roughly categorized into evaluations of even-age and uneven-age silvicultural systems. For example, the UAMP treatment regimes include three alternatives in which repeated periodic harvest entries are prescribed into perpetuity. Initially these entries constitute a conversion from a single-cohort to multiple-cohort stand structure. Subsequently, repeated entries generate new cohorts while maintaining continuous cover. Although cutting cycles exist, no rotation lengths are defined per se for UAMP; the three UAMP continuous-cover active management approaches represent three different uneven-age silvicultural systems. The Capitol Forest Study (CFS; app. 1) includes four even-age treatment regimes differing in regeneration method and length of rotation, each expected to differ in structural development, growth, and yield. The CFS also includes patch-wise selection and group selection alternatives leading to uneven-age management regimes.

Several of the studies on federal lands address a management scheme that cannot be easily categorized as even-age or uneven-age. For example, STUDS addresses management approaches for application to young even-aged stands being managed as LSRs under the NWFP. The silvicultural treatments in STUDS are designed to move stands from simple, even-age structure to more complex, multicohort structure. However, this is done with the caveat that once the stands reach a threshold age (which is defined as a surrogate for mean tree size), further manipulative entries will cease. The opportunity to introduce more than one or two additional cohorts between ages 35 and 80 years is limited. Thus, although this represents a conversion from an even-age system, the restriction on active management beyond a threshold age does not allow for management in an uneven-age system. Further, there remains reasonable question as to whether the conversion process initiated in one or two thinning entries can be maintained, or will the stands revert to an even-age condition without subsequent entries? Although the development of desired stand structures and ecological services from these young even-age Douglas-fir forests by means of forest reserve designation and passive management has not yet been demonstrated, the LSSE untreated controls provide demonstrations of the efficacy of passive management.

Most of the studies were initiated with a single prescribed entry; however, multiple entries were explicitly prescribed in the study plans of the CFS (Curtis et al. 2004) and UAMP (Tucker et al. 2001). The CFS and UAMP were, from the outset, evaluations of alternative prescriptions for silvicultural systems. Curtis et al. (2004) defined a silvicultural system as “a planned program of silvicultural treatments covering the life of a stand, from regeneration through intermediate operations to final

removal.” This definition of a silviculture system is similar to “classic” definitions of silvicultural systems found in silviculture textbooks such as Matthews (1989), Nyland (1996), and Smith et al. (1997).

Several of the LSSEs (e.g., DMS_IT, DMS_RT, DMS_RB, and STUDS) are currently in preparatory stages for second entries. Thus, these studies are transitioning from evaluations of silvicultural treatments to evaluations of silvicultural systems. With the publication of the revised study plan for DMS_IT, DMS_RT, and DMS_RB (Cissel et al. 2006), these studies may rightly be regarded as evaluations of silvicultural systems.

Matrix 4.2 and table 5 both indicate, for example, that DEMO has one unthinned control (i.e., no overstory removal treatment), one light overstory removal treatment, two different moderate overstory removal treatments, one heavy overstory removal treatment, and one complete overstory removal treatment (i.e., clearcut). It must be stressed that “light,” “moderate,” and “heavy” reflect relative categories of overstory removal because different LSSEs used different measures to define stand density (e.g., basal area, trees per acre, relative density). In general, however, heavy overstory removals retained less than one-third of the fully stocked basal area, moderate overstory removals retained one- to two-thirds of the fully stocked basal area, and light overstory removals retained more than two-thirds of the fully stocked basal area.

All of the LSSEs contain treatments without overstory removal, i.e., unthinned “control” treatments (matrix 4.2, table 5). However, only CFS and LTEP include clearcut treatments in which all trees with diameters larger than some small, minimum diameter were felled. Of these two, only CFS has treatments in all five overstory removal classes. One-third of the LSSEs have treatments in each of the four overstory removal classes other than the clearcut treatment.

In some cases, two treatments at an LSSE might have similar overall levels of overstory removal, but the treatments were considered different because of differences in the spatial patterns of overstory removals and other treatments (matrix 4.2). At DEMO, for example, the 40-percent aggregated retention and 40-percent dispersed retention treatments are both considered medium overstory removals. The spatial patterns of these two medium overstory removals are very different, however. In contrast to matrix 4.2, the total number of different overstory treatments is simply shown in a single row in table 5. The number of non-overstory treatments nested within a single overstory treatment is indicated by the number in parentheses in table 5. At FES, for example, “den augmentation” (i.e., creation of dens) and “no den augmentation” are two additional treatments nested within the no overstory removal and moderate overstory removal treatments (table 5).

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The wide range of density measures used in different LSSEs is apparent from the information summarized in matrix 4.3. Curtis's (1982) relative density was used in CFS, FES, and UAMP. Number of trees per acre was used by CWS, DMS_IT, DMS_RT, DMS_RB, LTEP, STUDS, and YSTDS. Basal area was used by DEMO and OHDS. Additional treatments described are planting, spatial distribution of coarse woody debris, spatial distribution of logging slash, organic matter removal, and road removal.

The initial LSSE treatments were variable in terms of the intensity and spatial pattern of overstory removal and the scale of treatment application (fig. 2). The x-axis in figure 2 indicates the treatment-wide percentage of fully stocked basal area retained following the initial overstory removal treatment. (Treatments for all LSSEs except DMS_RB are shown in fig. 2.) The range of treatments along the x-axis extends from clearcut treatments (i.e., no basal area retained) to unthinned control treatments (i.e., 100 percent of fully stocked basal area retained). The y-axis indicates the percentage of the total treatment area made up by the matrix of each LSSE treatment. The matrix is the "background" or dominant feature of the treatment-wide spatial pattern. For uniformly thinned stands (e.g., DEMO treatment 3b) and the unthinned controls, the matrix represents 100 percent of the total treatment area. Shading indicates residual overstory density, with lighter shades indicating more open residual canopies. Treatment scale for each LSSE is the average size of each treatment unit. The square labeled "10 acres" at the bottom of figure 2 represents an area of 10 acres.

To illustrate, the two clearcut treatments—CFS treatment 5a and LTEP treatments 5a through d—are shown as white squares in the upper left corner of figure 2. The sizes of the squares used to symbolize CFS treatment 5 and LTEP treatments 5a through d indicate that the average size of CFS treatment units is larger than that of LTEP treatment units. Because clearcuts cover all of the treatment area and have no residual overstory basal area, CFS treatment 5a and LTEP treatments 5a through d are shown as white squares in the upper left corner of figure 2. The control treatments for all LSSEs (100 percent residual overstory basal area and a matrix covering 100 percent of the total treatment area), in contrast, are shown as black squares clustered in the upper right corner of figure 2.

Each treatment-wide (or coarse-scale) spatial pattern is illustrated in figure 2 by the treatment matrix; for nonuniformly thinned stands, overstory removal gaps and patches of leave trees are shown by white and black dots, respectively. In general, the matrix as a percentage of total treatment area decreased as the overall complexity of the treatment-level spatial patterns increased. For example, DMS_IT treatment 3a in the lower right corner of figure 2 (x-axis value = 69 percent, y-axis value

= 60 percent) is a moderate overstory removal treatment, with 10 percent of the treatment unit cut to create circular gaps of different sizes (0.25, 0.5, and 1.0 acres) and 10 percent of the treatment unit left uncut as circular, unthinned patches (0.25, 0.5, and 1.0 acres). Portions of the variable-density thinnings at FES treatments 3a and b were designed to mimic openings caused by root rot (Carey et al. 1999b).

Not shown in figure 2 are additional (i.e., non-overstory) treatments such as planting to recruit understory cohorts. Underplanting in at least one treatment occurred at all but two LSSEs (DMS_RT and DMS_RB). The unthinned controls were underplanted at DMS_IT and STUDS. Additional treatments involving dead wood were implemented at LTEP and OHDS. At FES, additional treatments involve “den augmentation” either through the creation of nesting cavities or the installation of nest boxes to enhance populations of prey species.

Response variables measured at almost all of the LSSEs include over-, mid-, and understory vegetation, snags, woody debris, and the forest floor (matrix 6, table 6). Arboreal mammals, soils, and economic variables were measured each at a different set of three LSSEs. Similarly, bats, climate, hydrology and geomorphology, forest pathology, and roads were measured at two different pairs of LSSEs. The only response variables measured at a single LSSE were large mammals (at OHDS) and fish (at DMS_RB).

Although many of the same general categories of variables were sampled at multiple sites, very few specific variables were sampled identically at multiple sites. For example, although bats were studied at both CFS and DEMO, canopy use by bats was sampled at CFS and bat abundance was sampled at DEMO. Given that most response variables were not sampled across multiple LSSEs, a formal meta-analysis involving data from multiple sites appears impossible for most response variables. Exceptions to this include ubiquitous tree-level response variables such as diameter growth. However, it is possible that future studies may be established across multiple LSSEs, thereby enabling the same response variables to be measured at a range of sites.

Discussion

Value of the Large-Scale Silviculture Experiments

First, the LSSEs have value because they reflect the issues that caused them to come about—clearcutting, old growth, and ecosystem management. As a group, these LSSEs have focused on developing silvicultural alternatives to clearcutting as a harvest and regeneration method. The LSSEs are developing new knowledge about innovative silvicultural treatments and systems and their applicability to meeting a variety of ecological, social, and economic objectives associated with sustainable

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forest management. For example, two-thirds of the LSSEs test silvicultural methods to accelerate the development of late-successional forest structure in young forests.

All of the LSSEs evaluate the effects of silvicultural treatments on a wide range of response variables, which include conventional variables such as tree growth and less conventional variables such as lichens, song birds, and social perceptions. The primary experimental factor is manipulation of the overstory through harvest and, in some cases, snag creation. Additionally, some understory manipulation, primarily release or respacing of regeneration, tree planting, or creation of downed coarse wood is also included as an experimental factor. The focus in young-growth studies has been on thinning to increase spatial heterogeneity, to increase understory light levels, to promote understory development, to enhance the rate of large-tree development, or to address other combinations of objectives.

From an ecosystem management perspective, the LSSEs address questions surrounding the use of active management to affect the sustainable production of diverse values or the restoration of ecological conditions and processes necessary to produce desired values from regional forest ecosystems. The LSSEs all measure a variety of response variables as indicators of ecological function derived from different forest structures. Ecological structures are the tangible components of an ecosystem and the way in which they are arranged spatially. For example, the snags in a stand are ecological structures that may be described in terms of number per acre, diameter, height, species, and decay class. An ecological process permitted by the presence of the snags is their use by birds for nesting.

Second, the LSSEs have value because they are silviculture experiments conducted at operational scales, both spatially and temporally. Most involved scientists have accepted that the LSSEs conform to generally agreed-upon standards of experimental design. The value of the LSSEs as long-term field experiments addressing the long-term response of forest ecosystems to silvicultural manipulations cannot be emphasized strongly enough (Franklin 1989, 2005; Tilman 1989). The operational nature of the LSSEs also includes economic and logistical feasibility, which are dependent on ownership, site, and objective. Various operational contexts have influenced the degree to which study design and layout conform to idealized concepts of experimentation as applied in an agronomic model, particularly with respect to uniformity or stratification of experimental units and treatment randomization. In reviewing these studies, it is clear that for each study, unique balances were struck among experimental design, operational criteria, and logistical or financial constraints.

Third, the LSSEs are valuable because of the generally high level of credibility they have as forest management research endeavors with scientists, managers, and

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stakeholders such as environmental groups. One source of this credibility stems from the fact that a majority of scientists, managers, and stakeholders recognize that the LSSEs seek to answer research questions important to them. Another source of credibility comes from the recognition that the LSSEs conform to many of the “real world” constraints perceived by different groups. For many managers, the LSSEs have a high degree of credibility because the LSSEs are perceived as operational in terms of scale, harvesting practices, and—in many cases—environmental constraints such as riparian buffers. Another source of LSSE credibility for scientists and managers is that, to varying degrees, both groups have been involved in the design and implementation of the LSSEs. The fact that peers are directly involved with the LSSEs very likely contributes to the credibility with which scientists and managers view the LSSEs.

One great value of the LSSEs is as demonstrations of alternative forest management practices. For example, managers who have toured established LSSEs are far more willing than they would otherwise be to try innovative approaches on the lands they manage. Managers are implementing silvicultural practices based on innovations being evaluated in LSSEs before the results of the studies are known (Monserud 2002). By demonstrating a wide range of silvicultural alternatives to clearcutting, the LSSEs may provide land managers with increased credibility among environmental groups or other stakeholders who may have rejected silvicultural treatments on the basis that they are synonymous with clearcutting.

An extremely valuable consequence of the credibility the LSSEs have with scientists, managers, and stakeholders is that the LSSEs represent a common forum within which various, sometimes disparate groups can cooperatively interact on forest management issues. Interactions in such a common forum are far more likely to promote constructive dialog between groups that might otherwise have only interacted in the courts (Wondolleck and Yaffee 2000).

Limitations of the Large-Scale Silviculture Experiments

The value of the LSSEs as long-term studies highlights one of their limitations—the need to wait for long-term results. Because short-term responses of forest ecosystems to silvicultural treatments can be transient, initial results must be viewed with a degree of caution (Tilman 1989). The long-term nature of the LSSEs virtually guarantees that one or more of the treatment replicates at a given LSSE will be affected by some disturbance. For example, several treatment replicates at the southernmost LTEP installation were burned in the 2002 Biscuit Fire. It remains to be seen whether the loss of these treatment replicates will compromise the LTEP experimental design.

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Another limitation of the LSSEs is that it may be difficult to conduct a synthesis across LSSEs. To do so in a conventional meta-analysis requires identification of common currencies and a degree of commonality in experimental and sampling designs to meet statistical assumptions. Initial assessments would indicate that these requirements may not be well met across all of the LSSEs reviewed here. Overstory development probably holds the greatest potential for providing a common currency for cross-study synthesis but sampling schemes differ substantially among studies. For two Oregon studies, YSTDS and UAMP, the vegetation sampling schemes were designed very similarly; that of DMS is also fairly similar. These three studies are currently undergoing a synthetic assessment. Approaches that avoid some statistical assumptions may prove useful, although they are not as well known or understood by the scientific community. One such approach is Bayesian Belief Network, which is a methodology capable of incorporating data from a wide range of sources to develop correlation estimates among variables that permit prediction of the magnitude of response as well as the precision of the estimated response. Synthesis may also be based on models. Such models would be derived from response surfaces translated to empirical, process, or hybrid model structures. Typically, models developed to date address a narrow range of response parameters—most commonly vegetation and perhaps one to a few additional values.

The response variables being measured may be as much a reflection of the scientists involved as they are an underlying model of key regional indicators. This lack of strict common currency may limit potentials for meta-analysis, although it may also, in a coarse construct, permit identification of common trends in response to silvicultural treatments. Community-level responses may be more readily detectable than species-level responses. Recognizing this need, there is potential for future work to adopt common currencies for response. Two additional questions needing to be addressed are (1) what constitutes a pertinent response variable, and (2) are these variables likely to be consistent over time or will they change with changing issues and management paradigms?

Another limitation of the LSSEs is that—in some cases—participation by various disciplines has been tepid or waned over time. This may be due to varying levels of available funding or interested students; certainly, many LSSEs would have addressed more and varied questions had funding been available to do so.⁴ It also may be due to the different temporal and spatial scales at which various questions can be addressed. However, in some cases, it may be a failure of the

⁴Wilson, T. 2006. Personal communication. Wildlife biologist, Forestry Sciences Laboratory, 3625 93rd Ave. SW, Olympia, WA 98512.

“Field of Dreams“ (build it and they will come) premise. Whatever the reasons, levels of short- and long-term commitment to these large studies have been inconsistent among disciplines, programs, and institutions.

Role of Large-Scale Silviculture Experiments in Addressing Emerging Management Issues

Although there is an extensive body of literature describing silvicultural manipulation of stand structure, this work has focused predominantly on issues of stand development to maximize tree growth and yield. As such, the silvicultural systems often promoted uniform, early-seral, stand conditions and ignored structural elements necessary to meet habitat requirements for many late-successional organisms (Carey et al. 1999a). To achieve these objectives of heterogeneity requires new applications of evolving silvicultural principles and practices that result in definition of new silvicultural systems (Bailey and Tappeiner 1998, O’Hara 1998).

A commonality of the LSSEs is the use of silvicultural manipulation to enhance structural heterogeneity. Eventually an objective is to assess and understand the ways and extents to which alterations in structure result in changes in functionality. Examples of this include DMS_RB, which assesses the overstory structure influence on microclimate and associated consequences for amphibian habitats, and FES, which assesses the enhancement of spotted owl habitat through overstory manipulation and prey den enhancement. Structural objectives can be arrayed along a continuum from production of commercial wood products to development of late-successional/old-growth structure. Intermediate along the axis may be an objective to create midseral structures that support a combination of midseral species and high-quality wood production.

This group of studies is addressing several questions that have remained relevant over the 5 to 15 years since the studies were initiated. For example, under existing policy, federal lands designated as LSR have a capstone age beyond which harvest is tightly restricted. The question exists as to whether there are ecological objectives that would warrant active management, including density management, of LSR stands to a later age. Results from these LSSEs indicate that young (35- to 60-year-old), west-side Douglas-fir stands respond to thinning with a relatively rapid closure of the overstory canopy and decreased rates of crown recession. The upper limit to age at which these stands can demonstrate such canopy and crown responses has not yet been determined. Additionally, there is emerging evidence that underplanting of thinned forests can accelerate development of a second cohort. The question remains as to whether understory tree regeneration can persist and develop connectivity with the overstory without additional thinning entries

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to maintain understory light levels sufficient for growth and development of tree regeneration. Furthermore, to what extent do thinning practices to enhance understory recruitment have concomitant benefits to development of a large snag and downed wood supply and understory vegetation as habitat?

The LSSEs reviewed have been designed as long-term studies. As such, they are a unique resource for addressing long-term issues. For example, as a collective, the studies here could be envisioned as a barometer for regional dynamics of climate change. As distributed, they constitute a latitudinal array that may prove useful to regional monitoring. Although research natural areas (RNAs) and other reserved lands may have similar potential, these LSSEs are unique in that they include active management and will potentially provide insight to the interactive effects of climate change stresses and silvicultural practices on the provision of ecological, social, and commodity values. Additionally, it is worth noting that the LSSEs have permanent plots and a data record, which is likely absent for many RNAs (see footnote 1).

As indicated throughout this report, the principal driver of forest management has shifted in the past several decades from timber production to a broad suite of ecological and social benefits in addition to timber-related commodities. Interestingly, many of the ecological benefits are recently being viewed as services to be valued in economic terms, not unlike timber production. As ecological benefits or services attain broadly recognized value, there will be increasing interest in the production of these values through active management. Therefore, these LSSEs are potentially well positioned to address the emerging interests in nontimber forest products, carbon sequestration, and other ecological values when the questions involve management through silvicultural manipulation.

In an April 2006 LSSE workshop, representatives of federal and state agencies' regional and forest leadership identified fuels management, postfire salvage, invasive species, and implementation of adaptive management as priority issues. Fuels management, salvage, and invasive species are frequently associated with forest lands east of the Cascade Range. However, this does not mean that these LSSEs, located in the western portions of Washington and Oregon are irrelevant to fire and restoration issues. Although occurrence of fire is of lower historical frequency in the more mesic west-side forests, fire has had a substantial role in the development of the west-side Cascades and Coast Range forests. The regeneration following the vast Tillamook Fires in the mid-20th century exemplifies a vast area of young, even-aged forests within the range of the northern spotted owl for which structural heterogeneity is deemed inadequate and in need of restoration. Manipulation of young stand structure through thinning, as addressed in most of these LSSEs, is

having corollary effects on fuel loading. The vegetation, snag, and down wood sampling being conducted in many of these studies can be readily translated into measures of fuel loading.

Invasive species have been identified by the Forest Service—along with fire and fuels, loss of open space, and unmanaged recreation—as one of the four threats facing the Nation’s grasslands and forests in the early 21st century (Bosworth 2004). As with fire and salvage, invasive species are receiving more attention in east-side forests than in west-side forests. However, forests throughout the west side of the region are heavily traveled, and development in low-elevation forests is accelerating, particularly near urban centers. Thus, the threat of invasive species spreading throughout the west side of the region is great. The establishment of an invasive species at an LSSE may prove to be the ideal opportunity to monitor ecosystem responses to that invasive species.

Similarly, the LSSEs can contribute to the process of adaptively managing forests. The premise of adaptive management is that incorporating experimentation into management accelerates the pace of learning and, consequently, of adapting forest management practices as needed. Adaptive management is an important element of ecosystem management, as it encompasses monitoring to validate assumptions and overall effectiveness in meeting management objectives. A key role of the LSSEs within the broader context of developing management alternatives is in identifying and characterizing important ecological relationships and discerning appropriate variables to measure (or monitor) in order to assess the functionality of those relationships. Thus, the LSSEs reviewed here have the potential to contribute greatly to the adaptive management process.

Conclusions

Although not directly addressing all management issues that may arise, these LSSEs address information needs having a long-term context, and they were implemented at scales directly relevant to management planning and decision-making. They are generally founded on strong collaboration between scientists and managers. As a result, they serve to increase technical knowledge and abilities to meet objectives, increase science relevance through direct interaction among scientists and managers in a real-world context, increase credibility for management activities, assist managers in positioning to meet future issues, and provide new knowledge. The immediate value of these studies extends beyond development of knowledge, as the research process provides important learning opportunities for the managers, scientists, policymakers, and members of the public engaged in the studies.

In our attempt to identify the management needs and science questions being addressed by these LSSEs, there was a consistent theme—evaluation of manipulation of forest structure on the delivery of a variety of ecological, social, or economic values. Specific contexts differ as objectives range from ecologically sound application of even-aged silvicultural systems with an emphasis on wood production, to enhanced development of late-successional forest structures and habitat. Some reframing of issues may be occurring, such as increased interest in midseral forest structures as a management target for matrix lands. The question remains as to whether or not enhanced structural diversity in young stands translates to late-successional functionality. The value of structural heterogeneity to ecological processes and functions is likely scale-dependent, but a better understanding of the interactions between stand and landscape sources of variation is needed. In general, there needs to be increased knowledge about the relationships among forest management, aquatic and riparian habitats, and watershed function. Although these studies are generally focused on state or federal lands, collectively they are relevant to the full range of forest ownerships present in the region. Whereas these studies address the biological and technical aspects of forest management, it is important to understand that the public perceptions of management issues may not match those of the science or management communities. Therefore, it is important that the underlying questions for each of these studies be carefully considered and articulated.

Those studies that appear well positioned for the long run typically have support throughout the hierarchical structures of the partnering institutions.

Several challenges exist for this group of studies. With decreasing resources region- and stationwide, it is important to develop needed information efficiently. There is a need for synthetic efforts to fully capitalize on the body of information being generated in these studies. Although the studies have some commonalities, there are relatively few values that were consistently quantified across all studies that would facilitate a conventional meta-analysis. Another challenge for the studies will be finding the appropriate balance between value as a learning opportunity and the need for statistical rigor. This balance will determine the ways in which the information generated and the research process can be useful. Funding will always be a challenge for these studies as a group. It is important to note, however, that the data collection and entry processes may be relatively inexpensive components of the studies once the initial establishment has occurred. Potential keys to collective success are to prioritize the information needs, identify where that information can be best obtained, and, as appropriate, build geographic and inferential scope across studies.

Those studies that appear well positioned for the long run typically have support throughout the hierarchical structures of the partnering institutions. For example, DMS has developed an infrastructure consisting of a steering committee representing all partner institutions, a science liaison, and site coordinators representing each administrative unit on which study installations occur. The various management and science partners meet at least once per year to discuss logistics and to communicate progress and key findings. The DMS has held large workshops approximately biannually. Scientists participate with ID teams in addressing National Environmental Policy Act requirements for planned activities. The DMS scientists have provided briefings to BLM and PNW leadership teams. There is a strong effort at communicating the study in its various aspects to partnering and potential user groups.

Acknowledgments

We gratefully acknowledge the overall reviews of this report by John Cissel, Susan Hummel, and John Tappeiner. Helpful comments and suggestions were made at various points by numerous additional individuals, including (in alphabetical order) Richard Abbott, Keith Aubry, Bernard Bormann, Leslie Brodie, Lynn Burditt, Sam Chan, Robert Curtis, Robyn Darbyshire, Allan Derickson, William Emmingham, Jeffrey Foster, Cheryl Friesen, James Golden, Charles Halpern, Constance Harrington, Richard Haynes, Stuart Johnston, Margaret Kain, Craig Kintop, Mark Koski, Nancy Lankford, David Larson, Jose Linares, Sue Livingston, Kathleen Maas-Hebner, David Marshall, Jon Martin, Robert Monserud, Jon Nakae, Bob Obedzinski, Kathy O'Halloran, Deanna Olson, Peter O'Toole, James Perkins, Charles Peterson, Sharmila Premdas, Frank Price, Klaus Puettmann, Jewel Reid, Robert Ribe, Hugh Snook, Tom Spies, Frederick Swanson, Charles Thompson, Kim Titus, Stephanie Wessell, Duncan Wilson, and Todd Wilson. We greatly appreciate the dedicated efforts of Lynn Sullivan, Frank Vanni, Keith Routman, Tiffany Dong, and Jared Ranum in bringing this manuscript and companion Web site to fruition. We apologize if we have overlooked acknowledging anyone.

Metric Equivalentents

When you know:	Multiply by:	To find:
Inches (in)	2.54	Centimeters
Feet (ft)	0.3048	Meters
Miles (mi)	1.609	Kilometers
Square feet (ft ²)	0.0929	Square meters
Acres (ac)	0.405	Hectares
Trees per acre	2.471	Trees per hectare
Square feet per acre (ft ² /ac)	0.229	Square meters per hectare

Literature Citations

Anonymous. 1996. Demonstration of Ecosystem Management Options: a study of green-tree retention levels and patterns in western Oregon and Washington. Unpublished study plan. On file with: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Forestry Sciences Laboratory, 620 SW Main Street, Suite 400, Portland, OR 97205.

Bailey, J.D.; Tappeiner, J.C., II. 1998. Effects of thinning on structural development in 40–100-year-old Douglas-fir stands in western Oregon. *Forest Ecology and Management*. 108(1998): 99–113.

Bosworth, D.N. 2004. Statement of Dale N. Bosworth, Chief, USDA Forest Service, to the Committee on Appropriations, Interior and Related Agencies Subcommittee, House of Representatives. March 3, 2004. www.ourforests.org/fact/bosworthtestimony0304.pdf (December 27, 2006).

Carey, A.B.; Lipke, B.R.; Sessions, J. 1999a. Intentional systems management: managing forests for biodiversity. *Journal of Sustainable Forestry*. 9(3/4): 83–125.

Carey, A.B.; Thysell, D.R.; Brodie, A.W. 1999b. The Forest Ecosystem Study: background, rationale, baseline conditions, and silvicultural assessment. Gen. Tech. Rep. PNW-GTR-457. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 129 p.

Cissel, J.H.; Anderson, P.D.; Berryman, S.; Chan, S.S.; Olson, D.H.; Puettmann, K.J.; Thompson, C. 2006. BLM Density Management and Riparian Buffer Study: establishment report and study plan. Scientific Investigations Report 2006–5087. Reston, VA: U.S. Geological Survey. 144 p.

- Crisafulli, C.M.; Harrington, C.A. 1994.** Alternative silviculture in young Douglas-fir plantations: effects of stand composition and structure on plant and animal populations and on the production of forest products. On file with: C. Harrington, Forestry Sciences Laboratory, 3625 93rd Avenue SW, Olympia, WA 98512.
- Curtis, R.O. 1982.** A simple index of stand density for Douglas-fir. *Forest Science*. 28(1): 92–94.
- Curtis, R.O.; Clendenen, G.W.; DeBell, D.S.; DeBell, J.; Shumway, J.; Poch, T. 2001.** Silvicultural options for harvesting young-growth production forests. Part I. The stand-level silvicultural experiment. Rev. On file with: R. Curtis, Forestry Sciences Laboratory, 3625 93rd Avenue SW, Olympia, WA 98512.
- Curtis, R.O.; DeBell, D.S.; DeBell, J.D. 2004.** The Silvicultural Options Study. In: Curtis, R.O.; Marshall, D.D.; DeBell, D.S., eds. *Silvicultural options for young-growth Douglas-fir forests: the Capitol Forest Study—establishment and first results*. Gen. Tech. Rep. PNW-GTR-598. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 3–12.
- Curtis, R.O.; DeBell, D.S.; Harrington, C.A.; Lavender, D.P.; St. Clair, J.B.; Tappeiner, J.C.; Walstad, J.D. 1998.** Silviculture for multiple objectives in the Douglas-fir region. Gen. Tech. Rep. PNW-GTR-435. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 123 p.
- Forest Ecosystem Management Assessment Team. [FEMAT]. 1993.** Forest ecosystem management: an ecological, economic, and social assessment. Portland, OR: U.S. Department of Agriculture; U.S. Department of the Interior [and others]. [Irregular pagination].
- Franklin, J.F. 1989.** Importance and justification of long-term studies in ecology. In: Likens, G.E., ed. *Long-term studies in ecology: approaches and alternatives*. New York, NY: Springer-Verlag: 3–19. Chapter 1.
- Franklin, J.F. 2005.** Long-term studies: the basis for science based resource management. In: Peterson, C.E.; Maguire, D.A., eds. *Balancing ecosystem values: innovative experiments for sustainable forestry*. Proceedings of a conference. Gen. Tech. Rep. PNW-GTR-635. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 13–14.

- Harrington, C.A.; Carey, A.B. 1997.** The Olympic Habitat Development Study conceptual study plan. On file with: C. Harrington, Forestry Sciences Laboratory, 3625 93rd Avenue SW, Olympia, WA 98512.
- Helms, J.A., ed. 1998.** The dictionary of forestry. Bethesda, MD: Society of American Foresters. 210 p.
- Hurlbert, S.H. 1984.** Pseudoreplication and the design of ecological field experiments. *Ecological Monographs*. 54(2): 187–211.
- Intergovernmental Advisory Committee. [IAC]. 2006.** Prewrite meeting notes, March 8, 2006. <http://www.reo.gov/library/iac/2004-2006/2176IAC03082006.htm> (November 21, 2006).
- Little, S.; Bormann, B.; Bednar, L.; Wurtz, T.; Zasada, J.; McClellan, M.; Shainsky, L.; Boyle, J.; Castellano, M.; Amaranthus, M.; Harrington, C.; Zabowski, D.; Geist, M. 2000.** Long-Term Ecosystem Productivity (LTEP) program governing research plan for the integrated research sites. On file with: B. Bormann, Forestry Sciences Laboratory, 3200 SW Jefferson Way, Corvallis, OR 97331.
- Matthews, J.D. 1989.** Silvicultural systems. Oxford, England: Oxford University Press. 284 p.
- Microsoft. 2001.** Microsoft Excel 2002 software, Microsoft Windows 2000 Professional Edition. Redmond, WA: Microsoft Corporation.
- Monserud, R.A. 2002.** Large-scale management experiments in the moist maritime forests of the Pacific Northwest. *Landscape and Urban Planning*. 59(3): 159–180.
- Nyland, R.D. 1996.** Silviculture: concepts and applications. New York, NY: McGraw-Hill. 633 p.
- O’Hara, K.L. 1998.** Silviculture for diversity: a new look at multi-aged systems. *Journal of Forestry*. 96(7): 4–10.
- Omernik, J.M. 1987.** Ecoregions of the conterminous United States [1:7,500,000 map]. *Annals of the Association of American Geographers*. 77(1): 118–125. A geographic information system coverage and associated metadata of these ecoregions available from http://www.epa.gov/wed/pages/ecoregions/level_iii.htm (November 21, 2006).

- Peterson, C.E.; Maguire, D.A., eds. 2005.** Balancing ecosystem values: innovative experiments for sustainable forestry. Proceedings of a conference. Gen. Tech. Rep. PNW-GTR-635. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 389 p.
- Peterson, C.E.; Monserud, R.A. 2002.** Compatibility between wood production and other values and uses on forested lands: a problem analysis. Gen. Tech. Rep. PNW-GTR-564. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 51 p.
- Puettmann, K.J.; Poage, N.J.; Anderson, P.D. 2005.** Developing a network of large-scale management experiments in the Pacific Northwest [Poster]. In: 5th North American forest ecology workshop; 2005 June; Aylmer, Quebec, Canada. On file with: N. Poage, Forestry Sciences Laboratory, 620 SW Main Street, Suite 400, Portland, OR 97205.
- Reutebuch, S.E.; Harrington, C.A.; Marshall, D.D.; Brodie, L.C. 2004.** Use of large-scale silvicultural studies to evaluate management options in Pacific Northwest forests of the United States. *Forest, Snow and Landscape Research*. 78(1/2): 191–208.
- Smith, D.M.; Larson, B.C.; Kelty, M.J.; Ashton, P.M.S. 1997.** The practice of silviculture: applied forest ecology. 9th ed. New York: John Wiley and Sons, Inc. 537 p.
- Szaro, R.C.; Peterson, C.E. 2004.** Evolving approaches toward science-based forest management. *Forest, Snow and Landscape Research*. 78(1/2): 9–20.
- Tilman, D. 1989.** Ecological experimentation: strengths and conceptual problems. In: Likens, G.E., ed. *Long-term studies in ecology: approaches and alternatives*. New York, NY: Springer-Verlag: 136–157. Chapter 6.
- Tucker, G.F.; Emmingham, W.H.; Johnston, S.; Chan, S.S.; Minore, D.; Owston, P.; McCreight, R.W.; Hayes, J.P. 1993.** Commercial thinning and underplanting to enhance structural diversity of young Douglas-fir stands in the Oregon Coast Range. Adaptive COPE study plan. On file with: P. Anderson, Forestry Sciences Laboratory, 3200 SW Jefferson Way, Corvallis, OR 97331.
- Tucker, G.F.; Emmingham, W.H.; Overton, J.P.; McKee, W.A.; Mayo, J.H.; Cissel, J.H. 2001.** The H.J. Andrews Experimental Forest Uneven-Aged Management Project: study plan. On file with: P. Anderson, Forestry Sciences Laboratory, 3200 SW Jefferson Way, Corvallis, OR 97331.

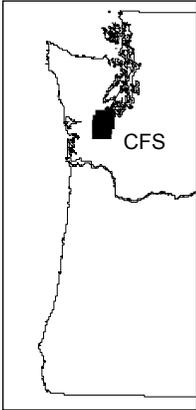
U.S. Department of Agriculture, Forest Service. [USDA FS]. 2006.

Forest Service Manual, Chapter 1990. <http://www.fs.fed.us/im/directives/fsm/1900/1990.txt> (November 21, 2006).

U.S. Department of Agriculture, Forest Service; U.S. Department of the Interior, Bureau of Land Management. [USDA and USDI]. 1994. Record of decision for amendments to Forest Service and Bureau of Land Management planning documents within the range of the northern spotted owl. Document 1994-589-111/00001. Washington, DC: U.S. Government Printing Office. 74 p. [plus attachment A: standards and guidelines].

Wondolleck, J.M.; Yaffee, S.L. 2000. Making collaboration work: lessons from innovation in natural resource management. Washington, DC: Island Press. 277 p.

Appendix 1—Capital Forest Study (CFS)



Initial Installation Years: 1998–2004

Primary Objectives: Create on-the-ground examples of a number of contrasting silvicultural systems (i.e., a range of disturbances and levels of retention) that can be evaluated for effectiveness in reducing visual and other environmental impacts of forestry operations, while providing high timber outputs over time. Monitor development of stands under these contrasting systems over an extended period with procedures that will provide quantitative estimates of vegetation

change and timber outputs, and statistically sound tests of differences between systems.

Pretreatment Conditions: 40- to 70-year-old, even-aged Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) stands.

Locations: Blue Ridge (46.8500°N, 123.1500°W), Copper Ridge (47.0333°N, 123.0667°W), and Rusty Ridge (46.9500°N, 123.2000°W).

Initial Treatments: 5 thinning treatments and 1 unthinned control each replicated 1 time at 3 locations.

No Overstory Removal (Control)

Control (1a). Provide a comparison with gains obtainable by the repeated thinning regime when some stands are held on an extended rotation as a means of adjusting currently unbalanced age distributions and reducing visual impacts on the landscape. Not thinned. Not planted. No woody debris or other initial treatments.

Light Overstory Removal

Repeated thinning (2a). Extended rotation with repeated, light, commercial thinnings. Thinned 100 percent of stand to a relative density (RD) of 40 to 50, where $RD = \text{basal area (ft}^2/\text{ac)} / \text{square root of the quadratic mean diameter (in), the diameter of the tree of average basal area}$. Not planted. No woody debris or other initial treatments.

Moderate Overstory Removal

Group selection (3a). Group selection uneven-age management, producing a unit consisting of five age classes on an approximately 50- to 75-year rotation. Thinned 80 percent of stand to RD 45 as needed. Cut 20 percent of stand in groups ranging from individual trees to groups of trees not larger than 1.5 ac on a 10- to 15-year cycle. Harvest groups dispersed throughout stand. Planted openings larger than 0.10 ac to Douglas-fir. Control competing vegetation as needed. No woody debris or other initial treatments.

Patch cut (3b). Patch-wise uneven-age management, producing a unit consisting of five age classes on an approximately 50- to 75-year rotation. Thinned 80 percent of stand to RD 45 as needed. Cut 20 percent of stand to create somewhat irregularly shaped 1.5- to 5.0-ac patches on a 10- to 15-year cycle. Harvest patches dispersed throughout stand. Patches planted to Douglas-fir and/or a mix of Douglas-fir and other species. Control competing vegetation as needed. No woody debris or other initial treatments.

Heavy Overstory Removal

Two-age (4a). Reserve shelterwood resembling a conventional shelterwood but with the overwood, or a portion of it, carried through the second rotation to provide large-diameter trees and high-quality material. Thinned 100 percent of stand to 15 trees/ac, with leave trees selected for spacing, vigor, and stem quality. Underplanted Douglas-fir. Control competing vegetation as needed. No woody debris or other initial treatments.

Complete Overstory Removal (Clearcut)

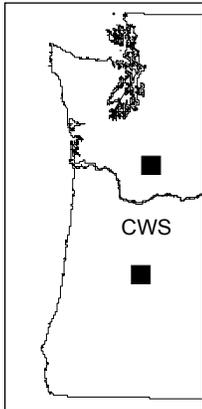
Clearcut (5a). Provide a direct quantitative comparison of clearcut costs and outputs with those of the other regimes. Clearcut 100 percent of stand, except for scattered groups of leave trees as needed to meet Washington Department of Natural Resources (WADNR) rules. Plant according to current WADNR practices. Control competing vegetation as needed. No woody debris or other initial treatments.

Response Variables: Over-, mid-, and understory vegetation; lichens, mosses, and bryophytes; birds; snags; social perceptions; wood production; economics; operational factors; forest floor.

Study Plan: Curtis, R.O.; Clendenen, G.W.; DeBell, D.S.; DeBell, J.; Shumway, J.; Poch, T. 2001 (revised; originally 1997). Silvicultural options for harvesting young-growth production forests. Part I. The stand-level silvicultural experiment. Study plan (silviculture). On file with: R. Curtis, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Forestry Sciences Laboratory, 3625 93rd Avenue SW, Olympia, WA 98512.

Web Site: <http://www.fs.fed.us/pnw/olympia/silv/selected-studies/blue-ridge/index.shtml> (last accessed December 6, 2006).

Appendix 2—Clearwater Study (CWS)



Initial Installation Years: 1994–1995

Primary Objectives: Evaluate short- and long-term growth and yield of overstory trees, stand differentiation, and variation in horizontal and vertical structure in response to alternative silvicultural prescriptions. Monitor short- and long-term population responses of small mammals, birds, amphibians, and vascular plants to the implementation of alternative silvicultural prescriptions. Accelerate the development of characteristics associated with late-successional forests.

Pretreatment Conditions: 10- to 13-year-old, even-aged Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) plantations.

Locations: Clearwater Study (CWS; 46.2560°N, 121.9980°W) and Very Young Stand Management Study (VYSMS; 44.2528°N, 122.2064°W).

Initial Treatments: 4 thinning × planting treatments and 1 unthinned control each replicated 5 times at the CWS location and each 1 time at the VYSMS location.

No Overstory Removal (Control)

Treatment A: untreated control (1a). Provide a comparison between rates of stand development and differentiation with and without postplanting treatments. Not thinned. Not planted. No woody debris or other initial treatments.

Light Overstory Removal

None.

Moderate Overstory Removal

Treatment B: thinned (no gaps), not planted (3a). Emphasize uniformity of species composition and stand structure with a long-term goal of high-value wood production. Thinned 100 percent of stand uniformly to 340 trees/ac by removing alternate diagonal rows. Not planted. No woody debris or other initial treatments.

Heavy Overstory Removal

Treatment C: thinned (1 gap size), planted (4a). Increase tree species diversity without making major changes in uniformity of tree spacing. Thinned 100 percent of stand uniformly to 340 trees/ac by removing alternate diagonal rows. Removed additional 100 trees/ac to create eight

uniformly distributed 42- × 42-ft (0.04 ac) gaps per acre. Planted with 100 trees/ac red alder (*Alnus rubra* Bong.) in gap centers. Planted 40 trees/ac western hemlock (*Tsuga heterophylla* [Raf.] Sarg.) and 40 trees/ac western redcedar (*Thuja plicata* Donn ex D. Don) on the gap edges. Planting was not as uniform as the treatment descriptions imply. No woody debris or other initial treatments.

Treatment D: thinned (3 gap sizes), not planted (4b). Increase structural heterogeneity. Treatment is designed to increase horizontal and vertical diversity (spatial heterogeneity) in the stand. Thinned 100 percent of stand uniformly to 340 trees/ac by removing alternate diagonal rows. Removed additional 100 trees/ac to create three different-sized gaps: 16 × 28 ft, 28 × 42 ft, and 42 × 42 ft. Not planted. No woody debris or other initial treatments.

Treatment E: thinned (3 gap sizes), planted (4c). Increase species, vertical and horizontal diversity. Treatment is an attempt to accelerate the development of conditions associated with old-growth forests through intensive silviculture. Thinned 100 percent of stand uniformly to 340 trees/ac by removing alternate diagonal rows. Removed additional 100 trees/ac to create three different-sized gaps: 16 × 28 ft, 28 × 42 ft, and 42 × 42 ft. Selected 30 large and vigorous trees/ac for growth enhancement. Kept 20 trees/ac of the growth enhancement trees in an open-grown situation to maximize growth. Planted 50 trees/ac red alder (7- × 7-ft spacing) in 28- × 41-ft and 41- × 41-ft gaps. Planted 75 trees/ac western hemlock and 75 trees/ac western redcedar (6 × 6 ft) in gaps of all three sizes. Planting was not as uniform as the treatment descriptions imply. No woody debris or other initial treatments.

Complete Overstory Removal (Clearcut)

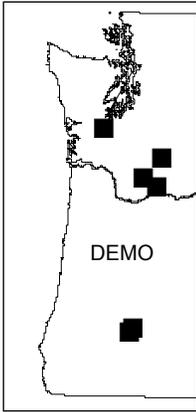
None.

Response Variables: Over-, mid-, and understory vegetation; mosses; snags; woody debris; climate; wood production; economics; forest floor.

Study Plan: Crisafulli, C.M.; Harrington, C.A. 1994. Alternative silviculture in young Douglas-fir plantations: effects of stand composition and structure on plant and animal populations and on the production of forest products. Study plan. On file with: C. Harrington, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Forestry Sciences Laboratory, 3625 93rd Avenue SW, Olympia, WA 98512.

Web Site: <http://www.fs.fed.us/pnw/olympia/silv/selected-studies/clearwater/> (last accessed December 6, 2006).

Appendix 3—Demonstration of Ecosystem Management Options Study (DEMO)



Initial Installation Years: 1994–1995

Primary Objectives: Determine how the level of retention following overstory removal influences biological values and social perceptions of mature, coniferous forests. Determine whether, for a particular level of retention, spatial pattern of retention is important. Determine whether a 15 percent level of retention is sufficient to maintain the organisms and processes that characterize late-seral forests in the Pacific Northwest. Determine which species or groups of organisms

are most sensitive to variation in the amount or spatial pattern of retention.

Pretreatment Conditions: 65- to 170-year-old stands dominated by Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco).

Locations: Butte (46.3720°N, 121.5920°W), Capitol Forest (46.8880°N, 123.1230°W), Dog Prairie (43.1960°N, 122.3060°W), Little White Salmon (45.8580°N, 121.7020°W), Paradise Hills (46.0030°N, 122.0430°W), and Watson Falls (43.2620°N, 122.2460°W).

Initial Treatments: 5 overstory removal treatments and 1 unthinned control each replicated 1 time at 6 locations.

No Overstory Removal (Control)

100-percent retention (1a). Provide untreated control. Not thinned. Not planted. No woody debris or other initial treatments.

Light Overstory Removal

75-percent aggregated retention (2a). High retention in aggregated fashion. Three circular 2.47-ac (1-ha) patches harvested in an evenly spaced triangular array removing 25 percent of the stand basal area. Created 2.6 snags/ac in harvested areas from dominant/co-dominant trees. Planted ~165 to 300 trees/ac to achieve minimum stocking; planting mix composed of 2 to 5 species that differed by geographic location. No additional woody debris or other initial treatments.

Moderate Overstory Removal

40-percent aggregated retention (3a). Moderate retention in aggregated fashion. Five undisturbed 2.47-ac (1-ha) circular patches retained evenly spaced within the

harvest unit. Planting and snag treatments identical to treatment 2a. No additional woody debris or other initial treatments.

40-percent dispersed retention (3b). Moderate retention in dispersed fashion. Dominant and co-dominant trees retained in an even distribution throughout the treatment unit; total basal area equivalent to that retained in treatment 3a. Planting and snag treatments identical to treatment 2a. No additional woody debris or other initial treatments.

Heavy Overstory Removal

15-percent aggregated retention (4a). Low retention (Northwest Forest Plan [NWFP] minimum) in aggregated fashion. Two undisturbed 2.47-ac (1-ha) circular patches retained at diagonally opposite positions within the harvest unit. Planting and snag treatments identical to treatment 2a. No additional woody debris or other initial treatments.

15-percent dispersed retention (4b). Low retention (NWFP minimum) in dispersed fashion. Dominant and co-dominant trees retained in an even distribution throughout the treatment unit; total basal area equivalent to that retained in treatment 4a. Planting and snag treatments identical to treatment 2a. No additional woody debris or other initial treatments.

Complete Overstory Removal (Clearcut)

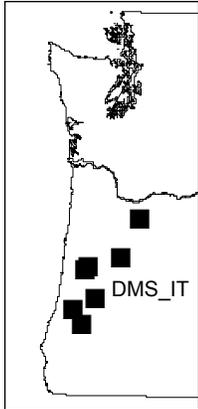
None.

Response Variables: Over-, mid-, and understory vegetation; lichens and bryophytes; arboreal mammals; small mammals; bats; birds; arthropods; amphibians; mollusks; woody debris; fungi; microclimate; hydrology; social perceptions; forest floor.

Study Plan: Anonymous. 1996. Demonstration of Ecosystem Management Options: a study of green-tree retention levels and patterns in western Oregon and Washington. Unpublished study plan. On file with: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Forestry Sciences Laboratory, 620 SW Main Street, Suite 400, Portland, OR 97205.

Web Site: <http://www.cfr.washington.edu/research.demo/> (last accessed December 6, 2006).

Appendix 4—Density Management Study, Initial Thinning (DMS_IT)



Initial Installation Years: 1996–2000

Primary Objectives: Evaluate effects of alternative forest density management treatments on important stand and habitat attributes in previously unthinned stands. Determine treatment effects on selected plant and animal taxa. Use these sites to develop operational approaches to implementation of new prescriptions, improve methods for effectiveness monitoring of plant and animal taxa, and share results of on-the-ground practices and findings

with land managers, regulatory agencies, policymakers, and the public.

Pretreatment Conditions: 50- to 70-year-old stands dominated by Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco).

Locations: Bottom Line (43.7722°N, 123.2364°W), Delph Creek (45.2656°N, 122.1592°W), Green Peak (44.3667°N, 123.4583°W), Keel Mountain (44.5281°N, 122.6319°W), North Soup (43.5658°N, 123.7772°W), OM Hubbard (43.2916°N, 123.5833°W), and Ten High (44.2806°N, 123.5183°W).

Initial Treatments: 3 thinning treatments and 1 unthinned control each replicated 1 time at 7 locations.

No Overstory Removal (Control)

Unthinned control (1a). Not thinned. Underplanted nine 1-ac areas with western hemlock (*Tsuga heterophylla* [Raf.] Sarg.) and western redcedar (*Thuja plicata* Donn ex D. Don). No woody debris or other initial treatments.

Light Overstory Removal

High-density retention (2a). Thinned 70 to 75 percent of stand to 120 trees/ac. Left 20 to 30 percent of stand as riparian buffers and/or leave islands of three sizes (0.25, 0.5, and 1.0 ac). Underplanted nine 1-ac areas with western hemlock and western redcedar. No woody debris or other initial treatments.

Moderate Overstory Removal

Moderate-density retention (3a). Thinned 60 to 65 percent of stand to 80 trees/ac. Cut 10 percent of stand to create circular gaps (0.25, 0.5, and 1.0 ac). Left 10 percent of stand in circular leave islands (0.25, 0.5, and 1.0 ac). Left 15 to 20 percent of stand as unthinned riparian buffers. Underplanted nine 1-ac areas with western hemlock and western redcedar. Planted gaps with western hemlock, Douglas-fir, western redcedar, and grand fir (*Abies grandis* [Dougl. ex D. Don.] Lindl.). No woody debris or other initial treatments.

Variable-density retention (3b). Thinned 10 percent of stand to 40 trees/ac, thinned 25 to 30 percent of stand to 80 trees/ac. Thinned 25 to 30 percent of stand to 120 trees/ac. Cut 10 percent of stand to create circular gaps (0.25, 0.5, and 1.0 ac). Left 10 percent of stand in circular leave islands (0.25, 0.5, and 1.0 ac). Left 15 to 20 percent of stand as unthinned riparian buffers. Planted gaps and underplanted 40 trees/ac overstory areas with western hemlock, Douglas-fir, western redcedar, and grand fir. No woody debris or other initial treatments.

Heavy Overstory Removal

None.

Complete Overstory Removal (Clearcut)

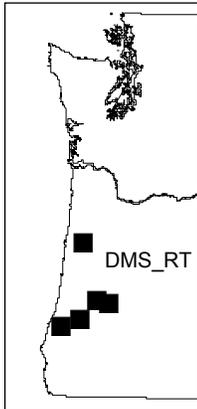
None.

Response Variables: Over-, mid-, and understory vegetation; lichens, mosses, and bryophytes; birds; arthropods; amphibians; mollusks; snags; woody debris; fungi; microclimate; forest floor.

Study Plan: Cissel, J.H.; Anderson, P.D.; Berryman, S.; Chan, S.S.; Olson, D.H.; Puettmann, K.J.; Thompson, C. 2006. BLM Density Management and Riparian Buffer Study: establishment report and study plan. Scientific Investigations Report 2006–5087. Reston, VA: U.S. Department of the Interior, Geological Survey. 144 p.

Web Site: <http://ocid.nacse.org/nbii/density/> (last accessed December 6, 2006).

Appendix 5—Density Management Study, Rethinning (DMS_RT)



Initial Installation Years: 1996–2007

Primary Objectives: Evaluate effects of alternative forest density management treatments on important stand and habitat attributes in stands thinned 25 to 30 years earlier to >100 trees/ac. Determine treatment effects on selected plant and animal taxa. Use these sites to develop operational approaches to implementation of new prescriptions, improve methods for effectiveness monitoring of plant and animal taxa, and to share results of on-the-ground practices and findings

with land managers, regulatory agencies, policymakers, and the public.

Pretreatment Conditions: 60- to 90-year-old stands dominated by Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco).

Locations: Blue Retro (43.2803°N, 124.0825°W), Little Wolf (43.4222°N, 123.6292°W), North Ward (43.7689°N, 123.2014°W), Perkins Creek (43.7142°N, 122.9131°W), and Sand Creek (44.8347°N, 123.5906°W).

Initial Treatments: 1 thinning treatment and 1 unthinned control each replicated 1 time at 5 locations.

No Overstory Removal (Control)

Unthinned control (1a). 25 to 30 years prior to initial DMS_RT treatments, overstory density reduced to >100 trees/ac in a single commercial thinning. Initial DMS_RT treatment: not thinned. Not planted. No woody debris or other initial treatments.

Light Overstory Removal

None.

Moderate Overstory Removal

Re-thin (3a). 25 to 30 years prior to initial DMS_RT treatments, overstory density reduced to >100 trees/ac in a single commercial thinning. Initial DMS_RT thinning: thinned 100 percent of stand to a clumpy distribution of 40 to 60 trees/ac. Not planted. No woody debris or other initial treatments.

Heavy Overstory Removal

None.

Complete Overstory Removal (Clearcut)

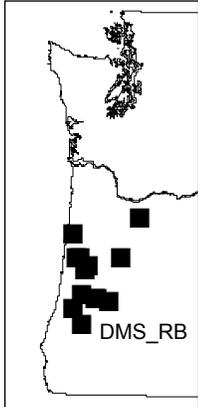
None.

Response Variables: Over-, mid-, and understory vegetation; snags; woody debris; forest floor.

Study Plan: Cissel, J.H.; Anderson, P.D.; Berryman, S.; Chan, S.S.; Olson, D.H.; Puettmann, K.J.; Thompson, C. 2006. BLM Density Management and Riparian Buffer Study: establishment report and study plan. Scientific Investigations Report 2006–5087. Reston, VA: U.S. Department of the Interior, Geological Survey. 144 p.

Web Site: <http://ocid.nacse.org/nbii/density/> (last accessed December 6, 2006).

Appendix 6—Density Management Study, Riparian Buffer (DMS_RB)



Initial Installation Years: 1996–2001

Primary Objectives: Characterize stream habitats and aquatic-dependent vertebrate diversity patterns in headwater stream networks. Examine effects of headwater aquatic vertebrate assemblages and their habitats of different riparian buffer widths within early successional forests subject to upslope timber thinning experiments; examine these findings in light of study of streamside-to-upslope vegetation, microhabitat, and microclimate regimes. Evaluate microclimate,

microsite, and light responses to upland density management treatments and different riparian buffers.

Pretreatment Conditions: 50- to 90-year-old stands dominated by Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco).

Locations: Bottom Line (43.7722°N, 123.2364°W), Callahan Creek (43.8347°N, 123.5906°W), Cougar (44.5117°N, 123.6636°W), Delph Creek (45.2656°N, 122.1592°W), Grant (44.5117°N, 123.7642°W), Green Peak (44.3667°N, 123.4583°W), Keel Mountain (44.5281°N, 122.6319°W), North Soup (43.5658°N, 123.7772°W), North Ward (43.7689°N, 123.2014°W), OM Hubbard (43.2916°N, 123.5833°W), Perkins Creek (43.7142°N, 122.9131°W), Schooner (44.9358°N, 123.8558°W), and Ten High (44.2806°N, 123.5183°W).

Initial Treatments: 4 buffer width treatments and 1 unthinned control each replicated once at some of 13 locations.

No Overstory Removal (Control)

Unthinned control (1a). Provide baseline characteristics. Provide maximum buffer capacity for bank stability, coarse wood recruitment, and microclimate moderation; no environmental challenge. Not thinned. Riparian areas not planted. No woody debris or other initial treatments.

Light Overstory Removal

Two site-potential tree heights buffer (2a). Provide high buffer capacity for bank stability, coarse wood recruitment, and microclimate moderation; low environmental challenge. Overstory thinned or clearcut upslope of unthinned buffer ~480 ft wide, measured as slope distance from stream. Riparian areas not planted. No woody debris or other initial treatments.

Moderate Overstory Removal

One site-potential tree height buffer (3a). Provide high buffer capacity for bank stability, coarse wood recruitment, and microclimate moderation; moderate environmental challenge. Overstory thinned or clearcut upslope of unthinned buffer ~240 ft wide, measured as slope distance from stream. Riparian areas not planted. No woody debris or other initial treatments.

Heavy Overstory Removal

Variable-break buffer (4a). Provide moderate buffer capacity for bank stability, coarse wood recruitment, and microclimate moderation; high environmental challenge. Overstory thinned or clearcut upslope of unthinned buffer of variable width, determined by onsite streamside ecological breaks in vegetation and slope character. Minimum buffer 50 ft wide, measured as slope distance from stream. Riparian areas not planted. No woody debris or other initial treatments.

Streamside-retention buffer (4b). Provide moderate buffer capacity for bank stability, coarse wood recruitment, and microclimate moderation; high environmental challenge. Overstory thinned or clearcut upslope of unthinned buffer of variable width, determined by trees that directly confer both streambank stability by their rooting position next to streams and overhead shading by their crowns extending over the channel. Buffer width generally defined by trees within 20 ft of the channel. Riparian areas not planted. No woody debris or other initial treatments.

Complete Overstory Removal (Clearcut)

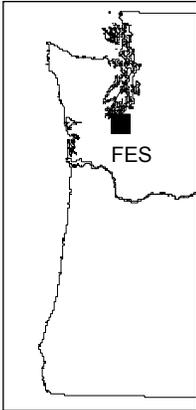
None.

Response Variables: Over-, mid-, and understory vegetation; lichens, mosses, and bryophytes; arthropods; amphibians; fish; mollusks; snags; woody debris; fungi; microclimate; hydrology; forest floor.

Study Plan: Cissel, J.H.; Anderson, P.D.; Berryman, S.; Chan, S.S.; Olson, D.H.; Puettmann, K.J.; Thompson, C. 2006. BLM Density Management and Riparian Buffer Study: establishment report and study plan. Scientific Investigations Report 2006–5087. Reston, VA: U.S. Department of the Interior, Geological Survey. 144 p.

Web Site: <http://ocid.nacse.org/nbii/density/> (last accessed December 6, 2006).

Appendix 7—Forest Ecosystem Study (FES)



Initial Installation Years: 1991–1993

Primary Objectives: Determine if woody plant species diversity, spatial heterogeneity in vegetation, and vertical diversity in vegetation can be manipulated through variable-density thinning and underplanting that do not require replacing the existing stand. Determine if enhancing the growth and diversity of woody plants will be accompanied by increased abundance and diversity of ectomycorrhizal fungi. Determine if increasing den availability through direct intervention (creating

cavities in live trees and adding nest boxes) will increase flying squirrel populations.

Pretreatment Conditions: 55- to 65-year-old, even-aged Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) stands.

Locations: Fort Lewis (46.9900°N, 122.6900°W).

Initial Treatments: 2 thinning × den augmentation treatments and 2 unthinned control × den augmentation treatments each replicated 4 times at 1 location.

No Overstory Removal (Control)

Control, no den augmentation (1a). Not thinned. Not planted. No den augmentation. No woody debris or other initial treatments.

Control, den augmentation (1b). Identical to treatment 1a but with den augmentation (i.e., nest boxes installed and/or cavities created).

Light Overstory Removal

None.

Moderate Overstory Removal

Variable-density thinning, no den augmentation (3a).

Root-rot thinning applied to ~15 percent of stand: low-vigor trees removed and apparently healthy trees retained, producing residual densities of ~16 trees/ac >7.9 in diameter at breast height (d.b.h.). Light thinning applied to 50 to 60 percent of stand: thinning of subordinate and codominant trees > 7.9 in d.b.h. to reduce the density of overstory to ~125 trees/ac with an average spacing of ~19 ft between trees. Heavy thinning applied to 25 to 30 percent of stand: thinning of subordinate and codominant trees > 7.9 in d.b.h. to reduce the density of overstory to ~75 trees/ac with an average spacing of ~24 ft between trees. Marking guidelines specified retention of all large standing dead trees and all deciduous trees. Not planted. No den augmentation. No woody debris or other initial treatments.

Variable-density thinning, den augmentation (3b).

Identical to treatment 3a but with den augmentation (i.e., nest boxes installed and/or cavities created).

Heavy Overstory Removal

None.

Complete Overstory Removal (Clearcut)

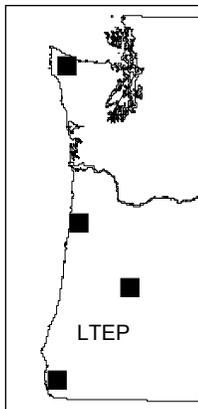
None.

Response Variables: Over-, mid-, and understory vegetation; arboreal mammals; small mammals; birds; arthropods; amphibians; snags; woody debris; fungi; soils; microclimate; forest pathology; roads.

Study Plan: Carey, A.B.; Thysell, D.R.; Brodie, A.W. 1999. The Forest Ecosystem Study: background, rationale, baseline conditions, and silvicultural assessment. Gen. Tech. Rep. PNW-GTR-457. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 129 p.

Web Site: http://www.fs.fed.us/pnw/pubs/gtr_457.pdf (last accessed December 6, 2006).

Appendix 8—Long-Term Ecosystem Productivity Study (LTEP)



Initial Installation Years: 1996–1998

Primary Objectives: Determine how potential and realized productivity are affected by the pathway along which succession is directed by management practices. Determine how altering the amount of periodic inputs of organic matter to the forest floor can influence long-term ecosystem productivity. Determine effects of underburning on the late-seral treatment.

Pretreatment Conditions: 70- to 100-year-old, even-aged stands dominated by Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco).

Locations: Hebo (45.2167°N, 123.7500°W), Isolation (44.0667°N, 122.4000°W), Sappho (48.0667°N, 124.2500°W), and Siskiyou (42.3333°N, 124.1667°W).

Initial Treatments: 1 thinning treatment, 2 clearcutting treatments, and 1 unthinned control each replicated 3 or 4 times at 4 locations.

No Overstory Removal (Control)

Control (1a). Not thinned. Not planted. No organic matter removal. No other initial treatments.

Light Overstory Removal

None.

Moderate Overstory Removal

Late-successional, organic matter retention (3a). Initial thinning to move stands into understory re-initiation phase. Thinned 100 percent of stand to ~80 trees/ac. Underplanted ~150 trees/ac shade-tolerant conifers (e.g., western hemlock [*Tsuga heterophylla* {Raf.} Sarg.], western redcedar [*Thuja plicata* Donn ex D. Don], Pacific yew [*Taxus brevifolia* Nutt.], sugar pine [*Pinus lambertiana* Dougl.]). Organic matter retained. No other initial treatments.

Late-successional, organic matter removal (3b). Identical to treatment 3a, but with organic matter removed.

Heavy Overstory Removal

None.

Complete Overstory Removal (Clearcut)

Early-successional, organic matter retention (5a). Re-initiate stand development with a stand that emphasizes early seral species for up to two-thirds of the rotation. Clearcut 100 percent of stand. Planted ~150 to 200 trees/ac of Douglas-fir and ~50 trees/ac of hardwoods (e.g., red alder [*Alnus rubra* Bong.], bigleaf maple [*Acer macrophyllum* Pursh]). Organic matter retained. No other initial treatments.

Early-successional, organic matter removal (5b). Identical to treatment 5a, but with organic matter removed.

Mid-successional, organic matter retention (5c). Re-initiate stand development with a stand that emphasizes Douglas-fir bole growth. Clearcut 100 percent of stand. Planted ~600 to 800 trees/ac of Douglas-fir. Organic matter retained. No other initial treatments.

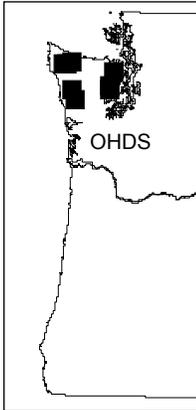
Mid-successional, organic matter removal (5d). Identical to treatment 5c, but with organic matter removed.

Response Variables: Over-, mid-, and understory vegetation; lichens; small mammals; birds; reptiles and amphibians; snags; woody debris; fungi; soils; climate; forest pathology; social perceptions; wood production; forest floor.

Study Plan: Little, S.; Bormann, B.; Bednar, L.; Wurtz, T.; Zasada, J.; McClellan, M.; Shainsky, L.; Boyle, J.; Castellano, M.; Amaranthus, M.; Harrington, C.; Zabowski, D.; Geist, M. 2000. Long-Term Ecosystem Productivity (LTEP) program governing research plan for the integrated research sites. On file with: B. Bormann, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Forestry Sciences Laboratory, 3200 SW Jefferson Way, Corvallis, OR 97331.

Web Site: <http://www.fsl.orst.edu/ltep/> (last accessed December 6, 2006).

Appendix 9—Olympic Habitat Development Study (OHDS)



Initial Installation Years: 1997–2006

Primary Objectives: Test management alternatives for their ability to accelerate development of characteristics associated with older stands. Test if accelerated development of the structures that are missing in the younger stands will increase the function of the ecosystem as habitat for forest-floor-dwelling terrestrial amphibians and small mammals.

Pretreatment Conditions: 35- to 62-year-old, even-aged stands dominated by Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco).

Locations: Bait (47.3900°N, 123.9100°W), Clavicle (48.0400°N, 124.2100°W), Eats (47.5700°N, 124.0400°W), Fresca (48.0500°N, 124.2900°W), North Fork Fulton (47.6500°N, 123.0000°W), Rail (48.0600°N, 124.0700°W), Snow White (47.9300°N, 122.9700°W), and Triton (47.6200°N, 123.0100°W).

Initial Treatments: 4 thinning × planting × coarse woody debris (CWD) treatments and 1 unthinned control each replicated 1 time at 8 locations.

No Overstory Removal (Control)

Control (1a). Not thinned. Not planted. No woody debris or other initial treatments.

Light Overstory Removal

None.

Moderate Overstory Removal

Variable-density thinning, not planted, coarse woody debris (CWD) clumped, slash dispersed (3a). Thinned 75 percent of stand to 75 percent of pretreatment basal area. Cut 15 percent of stand to create small gaps. Left 10 percent of stand as uncut patches (“skips”). Not planted. CWD clumped and slash dispersed. No other initial treatments.

Variable-density thinning, not planted, CWD dispersed, slash dispersed (3b). Identical to treatment 3a, but with CWD dispersed and slash dispersed.

Variable-density thinning, planted, CWD clumped, slash clumped (3c). Identical to treatment 3a, but native understory species planted or seeded in existing or newly created openings and with CWD clumped and slash clumped.

Variable-density thinning, not planted, CWD removed, slash dispersed (3d). Identical to treatment 3a, but with CWD removed and slash dispersed.

Heavy Overstory Removal

None.

Complete Overstory Removal (Clearcut)

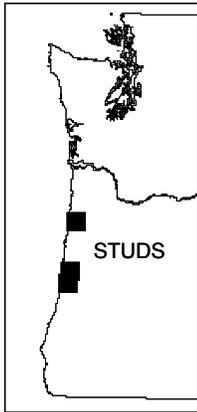
None.

Response Variables: Over-, mid-, and understory vegetation; mosses; large, arboreal, and small mammals; bats; arthropods; amphibians; mollusks; snags; woody debris; fungi; microclimate; wood production; operational factors; roads; forest floor.

Study Plan: Harrington, C.A.; Carey, A.B. 1997. The Olympic Habitat Development Study conceptual study plan. On file with: C. Harrington, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Forestry Sciences Laboratory, 3625 93rd Avenue SW, Olympia, WA 98512.

Web Site: <http://www.fs.fed.us/r6/olympic/ecomgt/research/habitat.htm> (last accessed December 6, 2006).

Appendix 10—Siuslaw Thinning and Underplanting for Diversity Study (STUDS)



Initial Installation Years: 1992–1993

Primary Objectives: Characterize the effects of thinning to increase structural heterogeneity and underplanting on stand composition, structure, vegetative diversity, and productivity in young, even-aged Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) stands of high site index in the Oregon Coast Range.

Pretreatment Conditions: 30- to 33-year-old, even-aged, Douglas-fir plantations.

Locations: Cataract (44.0700°N, 123.9500°W), Wildcat (45.2000°N, 123.7800°W), and Yachats (44.2800°N, 123.9400°W).

Initial Treatments: 3 thinning treatments and 1 unthinned control each replicated 1 time at 3 locations. All thinned treatments and unthinned control were underplanted with a 1:1 mix of Douglas-fir and western hemlock (*Tsuga heterophylla* [Raf.] Sarg.) at 10- × 10-ft spacing with root rot pockets planted to red alder (*Alnus rubra* Bong.). Imbedded within each overstory treatment were three underplanting trials. First, two 1-ac areas within each treatment unit were either underplanted with Douglas-fir and western hemlock at 15 × 15 ft (species alternating within rows), or left unplanted. In a second conifer species trial, a single subplot per unit was planted with Douglas-fir, grand fir (*Abies grandis* [Dougl. ex D. Don.] Lindl.), western redcedar (*Thuja plicata* Donn ex D. Don), western hemlock, Sitka spruce (*Picea sitchensis* [Bong.] Carr.), and Pacific yew (*Taxus brevifolia* Nutt.). Each conifer species was planted at a 4.9- × 4.9-ft spacing in 13 four-seedling clusters arranged as a 6 × 13 grid of randomly selected clusters, for a total of 52 seedlings of each species. A third planting trial consisted of red alder and bigleaf maple planted in alternate species rows of 16 seedlings at 7.9- × 7.9-ft spacing. A total of 48 seedlings of each hardwood species were planted on each treatment at each site. Conifer planting occurred the winter after the block was thinned; hardwood planting occurred in the winter of 1994 at all three sites.

No Overstory Removal (Control)

No thin (1a). Passive management. Provide internal reference. Not thinned. Underplanted (see above). No woody debris or other initial treatments.

Light Overstory Removal

Narrow thin (2a). Grow large overstory trees, create understory-midstory cohorts, recruit coarse wood. Three-step overstory reduction to minimum density, repeated release of underplanted trees and natural regeneration. Thinned 100 percent of stand to ~100 trees/ac. Underplanted (see above). Slash cut to facilitate 15- × 15-ft planting. No woody debris or other initial treatments.

Moderate Overstory Removal

Wide thin (3a). Grow large overstory trees, create understory-midstory cohorts, recruit coarse wood. Two-step overstory reduction to minimum density, single release of underplanted trees and natural regeneration. Thinned 100 percent of stand to ~60 trees/ac. Underplanted (see above). Slash cut to facilitate 15- × 15-ft planting. No woody debris or other initial treatments.

Heavy Overstory Removal

Very wide thin (4a). Grow large overstory trees, create understory-midstory cohorts, recruit coarse wood. One-step overstory reduction to minimum density, single release of underplanted trees and natural regeneration. Thinned 100 percent of stand to ~30 trees/ac. Underplanted (see above). Slash cut to facilitate 15- × 15-ft planting. No woody debris or other initial treatments.

Complete Overstory Removal (Clearcut)

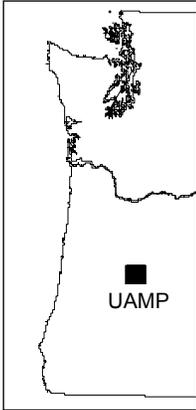
None.

Response Variables: Over-, mid-, and understory vegetation; mosses; snags; woody debris; microclimate; wood production; economics; operational factors; forest floor.

Study Plan: Tucker, G.F.; Emmingham, W.H.; Johnston, S.; Chan, S.S.; Minore, D.; Owston, P.; McCreight, R.W.; Hayes, J.P. 1993. Commercial thinning and underplanting to enhance structural diversity of young Douglas-fir stands in the Oregon Coast Range. Adaptive COPE study plan. On file with: P. Anderson, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Forestry Sciences Laboratory, 3200 SW Jefferson Way, Corvallis, OR 97331.

Web Site: None.

Appendix 11—Uneven-Aged Management Project (UAMP)



Initial Installation Years: 1997–2000

Primary Objectives: Determine the ecological and economic tradeoffs involved in converting young Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) plantations at mid-elevation in the central Oregon Cascades to a mixed-species and uneven-aged condition.

Pretreatment Conditions: 35- to 47-year-old, even-aged, Douglas-fir plantations.

Locations: H.J. Andrews Experimental Forest (44.2192°N, 122.2042°W).

Initial Treatments: 3 thinning treatments and 1 unthinned control each replicated 4 times at 1 location.

No Overstory Removal (Control)

Control (1a). Passive management. Provide internal reference. Not thinned. Not planted. No woody debris or other initial treatments.

Light Overstory Removal

Single-tree selection (2a). Repeated light commercial thinning to residual stocking levels creating understory light sufficient for establishment and recruitment of naturally regenerated shade-tolerant tree species, along with planted shade-intolerant tree species. With repeated entries, stands will ultimately consist of ~10 cohorts dominated by shade-intolerant species. Thinned 100 percent of stand from below to a relative density (RD) of 30, where $RD = \text{basal area (ft}^2/\text{ac)} / \text{square root of the quadratic mean diameter (in), the diameter of the tree of average basal area}$. Underplanted stand with an even mixture of Douglas-fir, western hemlock (*Tsuga heterophylla* [Raf.] Sarg.), western white pine (*Pinus monticola* Dougl. ex D. Don), and western redcedar (*Thuja plicata* Donn ex D. Don) at a 10- × 10-ft spacing. No woody debris or other initial treatments.

Group selection (2b). Repeated light commercial thinning combined with gap creation to favor recruitment by shade-intolerant tree species. Final stand consisting of ~10 cohorts, dominated by Douglas-fir. Thinned 90 percent of stand from below to RD 30. Cut 10 percent of stand to create circular gaps one tree height in diameter (~80 ft at initial treatment). Planted gaps with an even mixture of Douglas-fir, western hemlock, western white pine, and western redcedar at an 8- × 8-ft spacing (only gaps were planted). No woody debris or other initial treatments.

Moderate Overstory Removal

None.

Heavy Overstory Removal

Multi-storied stand (4a). Repeated heavy commercial thinning to residual stocking levels creating understory light levels sufficient for establishment and recruitment of shade-intolerant tree species, both natural and planted. Stands will ultimately consist of ~5 cohorts with first 2 to 3 dominated by Douglas-fir and later cohorts dominated by more shade-tolerant species. Thinned 100 percent of stand from below to RD 20. Underplanted stand with an even mixture of Douglas-fir, western hemlock, western white pine, and western redcedar at a 10- × 10-ft spacing. No woody debris or other initial treatments.

Complete Overstory Removal (Clearcut)

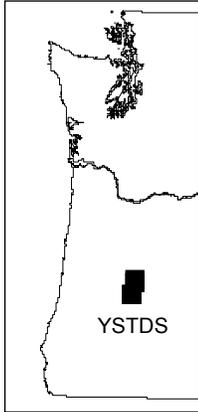
None.

Response Variables: Over-, mid-, and understory vegetation; lichens, mosses, and bryophytes; snags; woody debris; wood production; forest floor.

Study Plan: Tucker, G.F.; Emmingham, W.H.; Overton, J.P.; McKee, W.A.; Mayo, J.H.; Cissel, J.H. 2001. The H.J. Andrews Experimental Forest Uneven-Aged Management Project: study plan. On file with: P. Anderson, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Forestry Sciences Laboratory, 3200 SW Jefferson Way, Corvallis, OR 97331.

Web Site: http://www.fs.fed.us/pnw/bcftp/research_projects/UAMP.htm (last accessed December 6, 2006).

Appendix 12—Young Stand Thinning and Diversity Study (YSTDS)



Initial Installation Years: 1994–1996

Primary Objectives: Provide scientific information on the biological consequences of thinning. Provide agencies with experience in adaptive management that enhances both the creation of timber-related jobs and increased production and utilization of wood fiber.

Pretreatment Conditions: 35- to 45-year-old, even-aged, Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) plantations.

Locations: Blue River (44.1000°N, 122.2500°W), McKenzie Bridge (44.1786°N, 122.2708°W), and Oakridge (43.8857°N, 122.3438°W).

Initial Treatments: Three thinning treatments and one unthinned control each replicated 1 or 2 times at 3 locations.

No Overstory Removal

Control (1a). No treatment. Provide baseline. Not thinned. Not planted. No woody debris or other initial treatments.

Light Overstory Removal

Light thin, no gaps (2a). Timber production and wood quality. Thinned 100 percent of stand to 100 to 110 trees/ac. Not planted. No woody debris or other initial treatments.

Light thin, gaps (2b). Maximum horizontal and vertical heterogeneity. Patch-level approach to creating and enhancing the understory. Thinned 80 percent of stand to 100 to 110 trees/ac. Cut 20 percent of stand to create 0.5-ac gaps one tree height in diameter (~80 ft at initial treatment). Gaps planted. No woody debris or other initial treatments.

Moderate Overstory Removal

None.

Heavy Overstory Removal

Heavy thin (4a). Accelerate the development of late-successional habitat. Stand-level approach to creating and enhancing the understory. Thinned 100 percent of stand to 50 to 55 trees/ac. Underplanted. No woody debris or other initial treatments.

Complete Overstory Removal (Clearcut)

None.

Response Variables: Over-, mid-, and understory vegetation; small mammals; birds; snags; woody debris; fungi; soils; social perceptions; wood production, operational factors; forest floor.

Study Plan: No formal study plan found, although several study plan-like files exist. On file with: P. Anderson, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Forestry Sciences Laboratory, 3200 SW Jefferson Way, Corvallis, OR 97331.

Web Site: <http://www.fsl.orst.edu/ccem/yst/ystd.html> and <http://www.fsl.orst.edu/ccem/youngstd/home> (last accessed December 6, 2006).

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