

United States
Department of
Agriculture

Forest Service
Timber Management

Washington, DC



Proceedings of the National Silviculture Workshop

Silvicultural Challenges and
Opportunities in the 1990's

Petersburg, Alaska

July 10 - 13, 1989

Acknowledgement

The 1989 National Silviculture Workshop was held in Petersburg, Alaska, and the Stikine Area of the Tongass National Forest. The purpose of the workshop was to discuss, review, and share information about the silvicultural challenges and opportunities facing the Forest Service in the coming decade.

The Washington Office Silviculture Group appreciates the efforts of our hosts from the Tongass-Stikine Area, the Alaska Regional Staff, and the people of Petersburg for their gracious hospitality. We also extend our thanks to all who made presentations and participated during the workshop.

Silviculture Group
Timber Management Staff
Washington, D.C.

Tennis Jani

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1989 NATIONAL SILVICULTURE WORKSHOP ATTENDEES

R-1

P Dave Cawrse, Flathead NF
P Wendel Hann, RO
P Lee Harry, Beaverhead NF
P George Howe, RO
P Bob Naumann, RO

R-2

Charles Fudge, RO
P Christi Gordon, Pike-San Isabel NF
Gary Metcalf, RO
Jerry Simon, Shoshone NF
Willie Wisler, Black Hills NF
M Mike Znerold, RO

R-3

M Dick Bassett, RO
Charlie Bechtel, Kaibab NF
P Carol Holland, Apache-Sitgreaves NF
Jim Mercer, Tonto NF

R-4

P Doug Basford, Salmon NF
M Jerry Hamilton, RO
Ron Hamilton, RO
P Dave Holland, RO
P Glen Jacobsen, Payette NF
Joe Ragsdale, RO

R-5

Joyce Andersen, Klamath NF
P Ken Denton, RO
John Fiske, RO
Karen Jones, Tahoe NF
P Dave Thomas, Eldorado NF

WO

P Richard Fitzgerald, TM
Don Foth, TM
P Larry Gross, FPM
P Chris Jauhola, WL&F
P Larry Larson, LMP
Milo Larson, TM
P Richard G. Miller, TM
M Dennis Murphy, TM

R-6

P Dave Ellen, Mt. Hood NF
P Peggy Kain, Colville NF
P Walt Knapp, RO
Lynn Leppanen, RO

R-8

Olen Aycock, RO
P Robert Kitchens, RO
Carl Minehart, Ozark-St. Francis
Jack Reichert, NF's in Alabama
Jimmy Walker, RO

R-9

P Mike Lanasa, Hiawatha NF

R-10

Kent Barkhau, Chatham Area
Jerry Boughton, RO
P Steve Brink, RO
Don Carpenter, Stikine Area
P Gene Chelstad, RO
Max Copenhagen, RO
Dave Cottrell, Stikine Area
Mike Crane, Stikine Area
Pat Flanary, Chatham Area
Dave Gibbons, RO
Bob Green, Chugach NF
P Ron Humphrey, Stikine Area
Sue Kesti, Chugach NF
Jay Kittams, Stikine Area
Gene Lessard, Chugach NF
Bill Nightingale, Ketchikan Area
Mike Novy, Chugach NF
Ned Pence, Stikine Area
Tony Rodarte, Chatham Area
Miller Ross, Chatham Area
Jim Russell, Chatham Area
Dave Schmitt, Stikine Area
P Lynn Sprague, RO
M Pete Tennis, Stikine Area
Pat Tierney, Ketchikan Area
Mark Voight, Ketchikan Area
Lupita Wesseler, Stikine Area
Ron Wood, RO

RESEARCH

P Phil Aune, PSW
P James Baker, SO
Hugh C. Black, PNW
P Tom Crow, NC
P Dean DeBell, PNW
Bill Farr, PNW
P Russ Graham, INT
P David Loftis, SE
Nelson Loftus, TMR
P Dave Marquis, NE
P Bob Powers, PSW
P Wyman Schmidt, INT
P Jerry SESCO, Deputy Chief
P Wayne Shepperd, RM
P Boyd Wickman, PNW
Trish Wurtz, PNW
Andrew Youngblood, PNW
P John Zasada, PNW

P = Program
M = Moderator

Univ. of Alaska

P Dr. William R. Wood

BC Ministry of Forests

P Paul Diggle, Victoria, BC

City of Petersburg

P Arleen Pence, Mayor

1989 NATIONAL SILVICULTURE WORKSHOP
Petersburg, Alaska, July 10-13, 1989

"SILVICULTURAL CHALLENGES AND OPPORTUNITIES IN THE 1990's"

FINAL AGENDA

Monday July 10

Moderator: John Standerwick-R-10

- 1:00pm-1:30pm—**Welcome, Orientation, and Housekeeping**
Mayor--Arleen Pence, R-10--John Standerwick
Stikine Area Timber Staff--Ned Pence
- 1:30pm-1:40pm—**Introductions and Objectives**
WO-TM--Dick Fitzgerald
- 1:40pm-2:20pm—**Region 10 History and Orientation**
Deputy Regional Forester--Lynn Sprague
- 2:20pm-2:35pm—**TLMP 1 and TLMP 2--The Transition**
R-10--Steve Brink
- 2:35pm-3:10pm—**Tongass NF History and Orientation-Facts and Fiction**
R-10--Gene Chelstad and
Tongass-Stikine Forest Supervisor--Ron Humphrey
- 3:10pm-3:30pm—**BREAK**
- 3:30pm-4:30pm—**Forest Plan and NEPA Implementation**
WO-LMP--Larry Larson
- 4:30pm-5:00pm—**Silviculture in the 1990's**
Deputy Chief-Research--Jerry Sesco
- 5:00pm—**ADJOURN**
- Monday Evening-Salmon Bake-6:00pm-Sandy Beach Picnic Area*
Hosted by the Stikine River Chapter
of the Society of American Foresters,
Stikine Area Employees Association,
the Stikine Area Employees.

Tuesday July 11

Moderator: Dennis Murphy-WO-TM

What is a Silvicultural System?

- 8:00am-8:20am—A Practitioner's Perspective-R-1-Bob Naumann
8:20am-8:40am—A Research Perspective-INT-Wyman Schmidt

Alternative Silvicultural Systems-West

- 8:40am-9:00am—R-6-Colville NF-Peggy Kain
9:00am-9:20am—PNW-Dean DeBell

Alternative Silvicultural Systems-East

9:20am-9:40am-----R-9-Hiawatha NF-Mike Lanasa

9:40am-10:00am-----NE-Dave Marquis

10:00am-10:20am---***BREAK***

Alternative Silvicultural Systems-South

10:20am-10:40am-----R-8-Bobby Kitchens

10:40am-11:00am-----SO-Jim Baker

Alternative Silvicultural Systems-The Canadian Perspective

11:00am-11:40am-----BC Ministry of Forests-Paul Diggle

11:40am-12:00pm---***Question and Answer Period on Morning's Program***

12:00pm-1:00pm---***LUNCH***

Moderator: Jerry Hamilton-R-4

1:00pm-1:40pm---***Uneven-age Management-A Research Perspective***

INT--Russ Graham

1:40pm-2:00pm---***Uneven-age Management or Highgrading?***

R-4-Payette NF--Glen Jacobsen

2:00pm-2:20pm---***UAM and LMP Objectives and Monitoring***

R-6--Walt Knapp

2:20pm-2:40pm---***UAM and EAM, Genetic Impacts***

R-1--George Howe

2:40pm-3:00pm---***Forest Health Through Silviculture***

R-4--Dave Holland

3:00pm-3:20pm---***BREAK***

3:20pm-3:40pm---***Silviculture and Forest Health on the Pike-San Isabel***

R-2-Pike San Isabel NF--Christie Gordon

3:40pm-4:20pm---***Long Term Site Productivity and Silvicultural Systems***

PSW--Bob Powers

4:20pm-4:40pm---***Prescription Preparation on the Data General***

R-6-Mt. Hood NF--Dave Ellen

4:40pm-5:00pm---***Outplanting Trials of Stock from Different Nurseries***

PNW--John Zasada

5:00pm-----**ADJOURN**

Tuesday Evening-----Optional sessions, poster presentations, videos,
demonstrations, etc.--schedule will be announced.

Wednesday July 12

8:00am-5:00pm---**Field Trip on Mitkof Island**

(Agenda attached)

Wednesday Evening-Banquet---7:00pm-Banquet Speaker-Dr. William R. Wood
President Emeritus-University of Alaska

Thursday July 13

Moderator: Dick Bassett-R-3

8:00am-8:20am---**The Timber Purchaser-A Partner With a New Role**

R-1-Beaverhead NF--Lee Harry

8:20am-8:40am---**Negotiating For Better Silviculture**

R-1-Flathead NF--Dave Cawrse

8:40am-9:00am---**Ecological Basis for Regeneration of Southern Hardwoods**

SE--David Loftis

9:00am-9:20am---**The Forest Fertilization-Spruce Budworm Story**

PNW--Boyd Wickman

9:20am-9:40am---**Vegetation Management and Pesticide Use-What's Ahead?**

WO-FPM--Larry Gross

9:40am-10:00am---**Region 5 Pesticide Application Training**

R-5-Eldorado NF--David Thomas

10:00am-10:20am---**BREAK**

10:20am-10:40am---**Silviculture Research for Multiple Resource Management
in the Central Rocky Mountains**

RM--Wayne Shepperd

10:40am-11:00am---**Silvicultural Practices to Meet Non-timber Objectives**

PSW--Phil Aune and R-5--Ken Denton

11:00am-11:40am---**Second Growth Management and Black Tailed Deer in Canada**

BC Ministry of Forests--Paul Diggle

11:40am-12:00pm---**Silviculture for Threatened and Endangered Species**

WO-WL&F--Chris Jauhola

12:00pm-1:00pm---**LUNCH**

Moderator: Bob Blomquist-R-9

1:00pm-1:20pm—*A Broader View of Forest Ecology*

R-1--Wendel Hann

1:20pm-1:40pm—*Biological Diversity and Silvicultural Systems*

NC--Tom Crow

1:40pm-2:00pm—*High Tech Genetics-Electrophoresis Lab*

WO-TM--Dick Miller

2:00pm-2:20pm—*Growth Information-A New Method*

R-4--Doug Basford

2:20pm-2:40pm—*Pinyon-Juniper Management in Region 3*

R-3-Apache-Sitgreaves NF--Carol Holland

2:40pm-3:00pm—*Summary and Charge for the 1990's*

WO-TM--Dick Fitzgerald

3:00pm—————*ADJOURN*

National Silviculture Workshop
Field Trip Agenda
Wednesday, 7-12-89

ASSEMBLE at 8:00 am in Petersburg Ranger District parking lot (behind Post Office). If it's raining, we will meet upstairs in the Elk's Lodge.

Ron Humphrey	Welcome to Stikine Area field trip (5 min.)
Pete Tennis	Welcome to Petersburg Ranger District, introduction of Stikine Area speakers, and distribution of handouts (5 min.)
	Questions (5 min.)

Depart 8:15 am

Stop #1 YOUNG STANDS (20 yr. old stands at north end of loop road.)
Arrive 8:45 am; Depart 9:45 am

Dave Schmitt	Overview of area, location relative to Mitkof Island map and rest of tour, & description of stands (5 min.)
Ned Pence	Timber management on Stikine Area (10 min.)
Jay Kittams	Silviculture program & Management of young stands on Stikine Area (10 min.)
Dave Schmitt	Petersburg Ranger District silviculture program and description of surrounding stands (5 min.)
Ken Holbrook	Wildlife in young stands (5 min.)
Bill Farr	Management of young stands, and Stand Density Study (10 min.)
	Discussion & Questions (15 min.)

Stop #2 MATURE EVENAGED STAND (170 YR. OLD)
Arrive 10:15 am; Depart 11:00 am

Dave Schmitt	Description of stand and management Rx (5 min.)
Bill Pawuk	Plant association work & site description (10 min.)
E. Kissinger	Soils (site and other SE Alaska soils) (10 min.)
Bill Farr	FSL evenaged stand plots (10 min.)
	Discussion & Questions (10 min.)

Stop #3 OVERVIEW OF LE CONTE GLACIER
Arrive 11:15 am; Depart 11:45 am

Pete Tennis	Three Lakes Recreation Area, Stikine Le Conte Wilderness, recreation use of Loop Road, & overall District programs (15 min.)
Ned Pence	Road and rock source development (5 min.)
	Discussion & Questions (15 min.)

Stop #4 BLIND SLOUGH PICNIC AREA - Lunch (45 min.)
Arrive 12:15 pm; Depart 1:00 pm

Stop #5 OLD GROWTH STAND (walk across bridge and stop at turnout on
the way to the fish hatchery)
Arrive 1:10 pm; Depart 1:45 pm

Bill Pawuk	Site description (5 min.)
Ken Holbrook	Wildlife use in old growth stands (10 min.)
Bill Farr	Stand growth in old SE Alaska forests (5 min.)
	Discussion & Questions (15 min.)

Stop #6 CRYSTAL LAKE HATCHERY (walk from old growth stop)
Arrive 1:50 pm; Depart 2:45 pm

Bob Zorich	Crystal Creek Hatchery (30 min.)
Ken Holbrook	Stikine Area/Petersburg District Fisheries program & Trumpeter Swan area (10 min.)
	Discussion & Questions (15 min.)

Stop #7 PAPKE'S LANDING LOG TRANSFER FACILITY (LTF)
Arrive 3:00 pm; Depart 3:30 pm

Ned Pence	Log Transfer Facilities (including other uses) (15 min.)
	Discussion & Questions (15 min.)

Stop #8 BLIND RAPIDS
Arrive 3:45 pm; Depart 4:45 pm

E. Kissinger	Muskeg (5 min.)
	Walk to Rapids shelter (10 min.)
Jim McKibben	Stikine Area recreation (5 min.)
Ken Holbrook	Blind Slough Fishery (5 min.)
	Discussion & Questions (25 min.)
J. Standerwick	Closing comments
	Walk back to parking area (10 min.)

RETURN PETERSBURG RANGER DISTRICT OFFICE - Arrive 5:15 pm

SILVICULTURE IN THE 1990's

Jerry A. SESCO
Deputy Chief for Research
Washington, D.C.

INTRODUCTION

I appreciate the opportunity to participate in the 1989 National Silviculture Workshop. I'm honored to be part of what I know will be an excellent session on silviculture in the 90's. Chief Dale Robertson and Associate Chief George Leonard also asked me to extend their best wishes for a successful workshop.

If my calculations are correct, this is the sixth in a series of biennial National Silviculture Workshops that started in 1979. Previous workshops were held annually and addressed specific topics. Back in the 1970's, when I was a researcher at our Forestry Sciences Laboratory in Carbondale, Illinois, I recall that Region 9 hosted the '73 workshop on uneven-aged management.

As Deputy Chief for Research, I want to take this opportunity to acknowledge the good working relationship that has developed between my office and that of Jim Overbay, Deputy Chief for National Forest Systems. As an example, we are planning a joint Staff Directors meeting for September 1989; this may be a first.

In the short time I have this afternoon, I'd like to touch on four areas. First, I wouldn't be upholding my responsibility as Deputy Chief for Research if I didn't say a few words about Forest Service Research in general. Then, I'd like to highlight a few of the significant activities and attainments that have resulted from the long history of cooperation between National Forest Timber Management and Research. Next, I'd like to mention some of the issues I believe will, in fact must, drive our efforts in the future. Lastly, I'll close with some of my thoughts on what we must do together in the 1990's and beyond.

FOREST SERVICE RESEARCH – A BRIEF OVERVIEW

Forestry research in the United States predates the beginnings of the Forest Service in the late 1800's. Even as far back as the administration of John Quincy Adams, studies of the regeneration of live oak, a species valued for ship building timbers, were conducted on

the Santa Rosa Naval Timber reserve near Pensacola, Florida. In the mid-1870's, funding of about \$2,000 was appropriated to conduct an inventory of forest resources. Surprisingly, Gifford Pinchot wasn't all that supportive of forestry research. It was not until about 1908 when a staffer to Pinchot by the name of Raphael Zon came to him with a proposal to establish a network of experimental forests and ranges that Forest Service Research as we know it today got started. With the establishment of the Santa Rita Experimental Range in Arizona in 1908, Forest Service Research was on its way.

Since its early days, Forest Service Research has evolved to a national network of eight regional Forest and Range Experiment Stations and the Forest Products Laboratory. It conducts research in forest ecosystems ranging from the arctic tundra to the tropics and from the Pacific Trust Islands to Maine. Our research is conducted by about 720 scientists at 190 research work units at 74 locations. These scientists use some 80 experimental forests, ranges and watersheds and more than 200 Forest Service Research Natural Areas (RNA's) located on National Forest lands. In terms of the Forest Service budget for fiscal year 1989, Research has about 6 percent or \$140 million of the \$2 billion total. However, in comparison to 1980, Forest Service Research has 20 percent fewer scientists and 12 fewer locations. The fiscal year 1989 budget in constant dollars is about the same as it was in 1980, but costs of conducting research have continued to rise. In spite of this decline since 1980, we are still the largest forestry research organization in the world.

Research is funded in five budget line items: Timber Management Research (TMR); Forest Environment Research, including watershed, wildlife, range, and fish (FER); Forest Protection research including fire, insects, and disease (FPR); Forest Products and Harvesting Research (FPHR), and Forest Inventory, Economics, and Recreation Research (FIERR). I should note that International Forestry (IF) is located in the Research Deputy area, but contrary to what many think, it is not a line item anywhere in the Forest Service budget.

This group may be interested to know that timber management research with emphasis on the ecology,

silviculture, multiresource management, genetics and biotechnology, and growth and yield of the major forest types in the United States, is conducted in 56 Research Work Units (RWU) at 45 locations. This research directly involves about 200 scientists with an appropriation in fiscal year 1989 of \$27 million.

One last point, Forest Service Research has undergone self evaluation over the last couple of years. As part of this evaluation we had the Milliken Chapman Resource Group (an outside contractor) look at our "competitiveness" for resources and scientific standing, and our "responsiveness" to the needs of our clients and users of research information. The study showed that we have to clarify our mission and goals and we have to develop a strategic plan for the 1990's for Forest Service Research. We will complete the strategic plan early next year.

NFS TIMBER MANAGEMENT AND RESEARCH COOPERATION

We certainly hear a lot about partnerships in the Forest Service today, both internal and external partnerships. Perhaps one of the best internal partnerships I know of is that between NFS Timber Management and Timber Management Research. Following are examples of their numerous joint activities and attainments:

Reforestation Improvement Program (RIP)—RIP is a Service-wide effort initiated by TM and TMR in 1985 to intensively monitor tree nursery seedling growth, development, and survival. The primary goal of RIP is to increase our ability to predict reforestation success in field plantings.

Growth and Yield—A joint TM/TMR effort initiated in 1983 to coordinate the development, implementation, support, and maintenance of forest growth and yield systems for National Forest planning and management. The primary focus of this highly successful activity has been at the Region and Station level.

Long-term Productivity—In response to a national concern, TM, TMR, WS&A, and FER are in the initial stages of developing a Research and National Forest System program proposal to study the effects of forest management practices on long-term site productivity. An IPA position has been established to develop a proposed national research, development and application program.

Research Natural Area (RNA) Program—The primary objective of the RNA Program is to preserve pristine examples of forest, grassland, and aquatic types represented on National Forest System (NFS) lands.

RNA's serve: (1) to preserve and maintain natural diversity; (2) as reference areas for the study of succession; (3) for monitoring long-term environmental changes; (4) for on-site educational activities; and (5) as controls for measuring effects of resource management activities, e.g., as mandated under the monitoring provision of National Forest Management Act (NFMA). The Forest Service RNA program started in 1927. As of June 1989, there were 206 established RNA's and approximately 500 prospective RNA's identified in Forest Plans.

Tree Improvement—Forest Service research in genetics and forest tree improvement has provided the primary support for tree improvement action programs nationally. TM has been the focal point for the implementation of this research. For example, TM-WO in cooperation with R-5, PSW, and TMR-WO recently established the National Forest Genetic Electrophoresis Laboratory (NFGEL) in Placerville, California, to develop baseline data on the effects of timber management on the gene pool and to fingerprint genetically improved materials.

Activity Reviews—TMR Staff members, Assistant Station Directors with expertise in silviculture, Project Leaders, and scientists have participated as invited team members in Timber Management reviews of reforestation and timber stand improvement, and tree improvement and genetics programs. TM Staff members and Regional personnel have also participated as team members in Station Combined Program Reviews of research and administration.

National Silvicultural Workshops—Research scientists and administrators have always had an active part in the National Silvicultural Workshops. Research participation includes workshop planning, presentation of technical papers, and informal technical exchange between researchers and managers.

Silvicultural Certification Programs—Research scientists from several Stations including SE, SO, RM, INT, and PNW, have served as instructors for NFS silvicultural certification continuing education programs. This participation has increased the quality of the program and resulted in a better understanding of silvicultural problems and information needs.

Scientist Evaluation Panels—NFS personnel have served as peers and users for WO and Station research scientist grade evaluation panels.

Tongass Timber Supply Fund—Cooperative funding to PNW from the Regional Forester, R-10.

Silvicultural Systems for the Major Forest Types of the United States—This publication, designated as Agricultural Handbook 445, provides a concise but comprehensive summary of the state-of-knowledge on management opportunities for each of 48 major forest types in the United States. Copies have been provided to all Forest Service employees who are involved in land management decisions. Publication of this "Handbook" was a joint undertaking by personnel from Research, National Forest System, State and Private Forestry, and the Office of General Counsel.

The Scientific Basis for Silvicultural and Management Decisions in the National Forest System—This soon to be published General Technical Report (WO-55) updates and expands upon the information provided to Congress in the 1976 compendium of papers. Prepared by National Forest and Research personnel, it is a basic primer on the scientific basis for silviculture that should help those interested in the management and uses of the forest understand the considerations and evaluation processes our professionals go through in developing prescriptions to manage our National Forests.

I believe that these examples tell the story of a very productive and long-term partnership between Research, NFS, and S&PF.

ISSUES AND CONCERNS FOR THE FUTURE

During the latter part of the 20th century many people in the United States left their farms and moved into cities or into rural communities. One result of this migration has been a decline in the number of people with an appreciation for "timber" management, another has been an increase in the public's awareness and concern for national and global environmental issues. I don't have to tell you that public opinion differs widely concerning the management of our forest resources, especially of our National Forests. Following are some of the critical issues and concerns that I believe will affect our future research and management efforts.

Global Climate Change—How will management of our forests influence and be influenced by global climate change? Current air pollution research has revealed complex forest/atmospheric interactions. Global warming from greenhouse gases, namely carbon dioxide and methane, may dramatically alter the equilibrium temperature of the earth and precipitation patterns. This climate change could ultimately affect the composition, productivity, health, and diversity of forests everywhere.

We feel that our research scientists must add facts to this emotionally charged debate. "Forest Health, Productivity and Diversity in a Changing Atmospheric Environment" is a 10-year Forest Service research program being developed to: (1) understand processes governing atmospheric effects on forests; (2) determine the effects of forest management on the atmosphere; (3) monitor long-term effects of atmospheric change on forest conditions; and (4) help define management options.

Deforestation—Tropical deforestation is no longer someone else's problem. Newspaper, magazine, and television documentaries utilize photos and satellite imagery to emphasize the need for increased protection of this declining forest resource. Rightly or wrongly, the American public transfers this image of excessive deforestation in the tropics to timber harvesting practices on both public and private lands in the United States. They ask: Why are we cutting trees? Why do you clearcut? How does the United States contribute to global warming?

Currently the Forest Service has a program of tropical forest management and research, and provides technical assistance, training, and related natural resource expertise to the U.S. Agency for International Development (USAID), the Peace Corps, and developing countries. We are now developing an expanded tropical forestry program that draws on Forest Service strengths as a natural resource management agency to meet assistance needs identified by the United Nation's *Tropical Forestry Action Plan*, coordinated by the Food and Agriculture Organization (FAO). Our goal is to assist developing countries to reduce tropical deforestation and to manage, use, and protect vital tropical forest resources.

Threatened, Endangered, and Sensitive Species—As private forest lands are harvested or developed, our public lands, especially the National Forests, will be expected to provide the major source of habitat for many threatened, endangered, and sensitive (TES) plant and animal species. Providing the proper habitats and protecting viable populations of these TES species sometimes conflicts with planned timber management and harvesting activities. At least 166 of the 531 species currently on the federal list as threatened or endangered, occur on National Forest System lands. Some of these species such as the red-cockaded woodpecker (endangered) in the pine types of the South and the northern spotted owl (sensitive) in old-growth stands of the Pacific Northwest have had a significant impact on our research program and land management prescriptions.

The Forest Service has already directed considerable research toward resolving conflicts involving threatened, endangered and sensitive species and we plan to accelerate our efforts in the 90's. The ultimate goal of this

priority research program is to provide the information, guidelines, and technology needed to protect and recover threatened, endangered, and sensitive plant and animal species.

Biological Diversity—The Forest Service Steering Committee on Biological Diversity or Biodiversity defines the term as: "The variety of life and its many processes on earth." Biodiversity includes all life forms and the millions of processes, pathways, and cycles that link individual organisms into populations, ecosystems, and ultimately the entire biosphere. The protection and enhancement of biodiversity emerges as one of the pressing environmental issues for the 90's. The issue centers on losses or potential losses of species, biological communities, and ecosystems in specific areas, for example the old-growth forests of the Pacific Northwest and southeast Alaska. The Forest Service role in conserving biodiversity includes management of the National Forest System, Research programs, International Forestry activities, and State and Private Forestry assistance.

Many Forest Service research studies provide information and technology needed to conserve the variety of life in the Nation's forested ecosystems. The current research program addresses: threatened, endangered, and sensitive species; old-growth forests, riparian areas, and other special communities; genetic variation within and among forest stands; and silvicultural alternatives for managing species composition and stand structure. We plan to expand our program to increase knowledge of the basic principles of biodiversity such as species sensitivities to management activities, population viability, critical habitat requirements, analysis of cumulative effects, genetic structure, and landscape ecology.

A unique challenge and opportunity is presented by these issues and concerns. The challenge to the silviculturist is to protect and enhance ecological values such as biodiversity, while continuing to manage the Nation's forests to meet people's needs for timber, water, wildlife and fish, recreation, and minerals.

WHAT MUST WE DO TOGETHER IN THE 1990'S AND BEYOND?

Forest research already contributes much toward ensuring continued growth, productivity, and use of our forest lands. Results of silvicultural research have led to the development of guides for managing and regenerating most of the major forest types in the United States and have provided growth and yield information for many species and cultural practices. New and improved products such as reconstituted structural wood panels from low-quality hardwood have been developed. Research has provided

ways to prevent and control unwanted fires and to reduce the impacts of insect and disease organisms on the Nation's forests. Guidelines have been developed that integrate management for tree growth and timber production with habitat requirements for wildlife and fish and with practices that protect water quality and environmental values.

We take pride in our many past achievements and contributions. At the same time we realize that cooperative activities involving Research and the National Forest System will be increasingly important to the future use and management of our National Forests. The following are my thoughts on what we must do together in the 1990's:

—We need to find ways to accommodate rising demands on the uses of all forest resources while at the same time maintaining timber productivity. That is, we need to optimize timber productivity while meeting the needs for the protection, enhancement, and use of the forest environment.

—Specific areas we need to look at include development of viable yet flexible silvicultural systems and practices that will withstand the test of time. It's okay to talk about alternative silvicultural systems, but let's make sure that our discussions include both even- and uneven-aged management. These systems and practices should not only look good today, but must provide the tree species, quality, quantity, and forest environment that we seek for the future.

—We need to find environmentally acceptable ways to control competing vegetation. This might include improved herbicides, prescribed fire, mechanical methods, timing of practices, biological agents, or a combination of all these tools.

—The area of genetics, including biotechnology, needs more attention to see if we can meet some of the challenges to our tree improvement programs for better growth, quality, and pest resistance.

We could discuss many other areas for cooperative efforts such as development of: improved logging and utilization technologies, soil management guidelines for maintaining long-term forest productivity, artificial intelligence systems to help solve problems or to develop silvicultural prescriptions, improved or new wood products, and management alternatives for old-growth associated wildlife species. However, there is not time to do that. There is time, however, for you to adopt some of these items and build plans for the 90's on how we can work together to solve these problems to provide a

healthier, more useful, and aesthetically pleasing forest for our publics.

Advances in the practice of silviculture in the 1990's and beyond require that we: (1) reverse the downward trend in funding and staffing for silviculture both in Research and in the National Forest System; (2) develop stronger linkages between researchers and managers in all disciplines; and (3) not ignore past management

experience and research results in developing future silvicultural prescriptions and management alternatives.

Since this is the last Silviculture Workshop of the 1980's, I think that the time is ripe to make a commitment for the next decade and beyond. The objectives and program developed for this workshop are a step in that direction.

SILVICULTURAL SYSTEMS: A PRACTITIONER'S VIEW

John R. Naumann
Regional Silviculturist
U.S. Forest Service Northern Region¹

ABSTRACT

Silvicultural systems, with their conservative origins in Europe, may not be seen as compatible with current challenges facing forest managers. We must use innovation in prescribing silvicultural treatments that will achieve the desired result, but we do not need to invent a new silviculture and a new terminology to achieve our goals. There is a great deal of flexibility in the concepts described by established terminology. Enlightened use of this terminology will insure effective communication, professional credibility, and indicate a course of action to follow into the future. Our challenge is to adapt existing silvicultural systems to solve our emerging problems.

INTRODUCTION

What is a silvicultural system? It is a widely expressed idea without much documentation. Some early 20th Century textbooks (Fernow 1902; Toumey 1928) make no reference to silvicultural systems. The 1944 Edition of SAF Terminology does not define them. So where does this idea of silvicultural systems come from, what does it mean, and what utility does it have for us in the 1990's? The real question is: are we going to practice a new silviculture in the future or will the old terms and concepts suffice?

HISTORY

The latest definition in SAF Terminology (1971) provides some clues to the history of silvicultural systems. This definition says that a silvicultural system is "a process, following accepted silvicultural principles, whereby the crops constituting forests are tended, harvested, and replaced, resulting in the production of crops of distinctive form." Accepted principles, crop production, and distinctive forms are words that imply management, volume yield, stability and control. Most, if not all of our accepted silvicultural principles, as well as the idea of forest regulation and sustained yield, came from Europe where a timber shortage, a stable demand, and an economic policy of self sufficiency in the 1800's encouraged a

regimented and unchallenged forestry practice (Behan, 1975; Davis and Johnson 1987).

In this country, a forestry practice that emphasized a sustained supply of timber following straightforward principles whereby forest crops were "tended, harvested, and replaced," met with general public acceptance until recently. Now, standard practices inherited from Europe and applied with our traditional understanding of silvicultural systems seem to no longer work in the presence of fluctuating economies, legal mandates to manage more than timber yields, intense public feelings for non-commodity forest values, and reactive political processes.

The basis for silvicultural systems is found more in management and regulation of yields than in the principles of forest ecology or social and political concerns. The conditions we experience today are very different from the conditions that fostered the idea of silvicultural systems. It is not surprising that practicing silviculture in different ways to satisfy new needs and desires from the forest makes many of us feel uncomfortable.

ADAPTING SILVICULTURAL SYSTEMS

It has been generally recognized of silviculture in the United States that it is applied in too rigid a fashion. Perhaps that has been the safest or most economic course to follow. We are learning, however, that an inflexible application of silvicultural practices often creates problems. We are becoming painfully aware, for example, that a classic clearcut has a look only a forester can love. David Smith, in his 1962 text recognized that, "a good silvicultural system is not chosen but formulated as a solution to a specific set of circumstances." Those circumstances today include not only a goal of regulation, but also the need to manage multiple resources in a manner acceptable to the public.

Do we need to create and name a new silviculture? We hear of practices like "sloppy clearcuts" or "modified shelterwoods," all under the heading of alternative silvicultural systems. Maybe we feel that by using a new

¹ Presented at the National Silviculture Workshop, Petersburg, Alaska, July 10-13, 1989.

name for a practice we will be recognized as responsive and willing to change. The wisdom of David Smith (1962) again applies: "When the important act of inventing the solution has proceeded far enough, the less important step of attaching a name to it can be taken." "The standard terminology should be used to the extent of its limited capacity." In my opinion, standard terminology offers ample opportunity to fit today's needs if we recognize that this terminology allows a wide range of interpretation.

We need to focus on the intent of the prescribed treatment. For example, does the harvest create an even or uneven-aged stand? Will the proposed action replace the stand or just modify its condition? We also need to understand all of the available terminology. What about "reserve" trees? These are trees or groups of trees in an area being regenerated that are kept for part or all of the next rotation. Do we understand "accessory systems?" These are silvicultural systems derived from one or more of the basic systems and not dependent on any particular method of regeneration.

There are several good reasons why we should retain the concept of silvicultural systems and use existing terminology. First, this forms the basis for informed communication. Effective communication about harvest practices are needed between individuals, organizations, and even between countries. The SAF Terminology is an international effort. There is no practical way we are going to change or invent many new silvicultural systems and terms and still retain effective communication.

The second reason for using existing terminology and concepts is professional credibility. The actions we take in the Forest are based upon a body of science that is understood by our existing terminology. These concepts and terms are the link to this science. The professional credibility of Foresters is challenged today. We need to provide clear and reliable testimony to what we are doing in the forest. Consider the credibility of a forester who is not sure if 5-acre openings are clearcuts or group selections, but concludes that it really doesn't make any difference because the public doesn't object.

The third reason for using the concept of a silvicultural system is the view it provides of the future (Smith, 1962). It is truly a planning device that relates a future sequence of actions to the present harvest activity. Those future actions may be changed, but if we understand the concept of the silvicultural system, we know the general course to follow over time.

CONCLUSION

A silvicultural system is a concept that should not be limited by its conservative origins in Europe. There is a great deal of flexibility in the sound concepts expressed by established terminology. Our challenge is to make use of this flexibility within the limits implied by the terms. There are other more important limits. Soil and climate, ecosystem dynamics including insects and diseases, and the extent of our knowledge all place constraints on our flexibility. Ignoring these limits helped get us into trouble with clearcutting on some sites. Let's not let the same kind of ignorance get us into trouble with the inappropriate use of uneven-aged management.

There is some recently popular nomenclature that makes little sense. This vernacular speaks of "alternative silvicultural systems", and a "new silviculture." I think we should stop using these labels. They beg the question: alternative to what? They imply that past practices were faulty. That is selling short our silvicultural practices on the National Forests. The problem we should address today is one of application. It makes more sense to pursue a strategy of adapting existing systems to solve our emerging problems. If we can adapt, we will maintain effective communication, insure our professional credibility, and project a clear image of our silvicultural practice into the future. Most importantly, we can be sure that our practices will be effective in managing the resources for which we are responsible.

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WHAT IS A SILVICULTURAL SYSTEM—A RESEARCH PERSPECTIVE

Wyman C. Schmidt
Project Leader and Research Silviculturist
Intermountain Research Station, Forest Service
U.S. Department of Agriculture,
Bozeman, Montana

ABSTRACT

Silvicultural systems should mean the same to researchers and practitioners. Stability in terminology is important for communication in both time and space. Silvicultural systems provide a framework for research results that are stratifiable, identifiable, communicable, repeatable, quantifiable, and credible. Care should be taken in any revisions of the terminology. If additions are necessary, they should be done in a hierarchical fashion, retaining the basic framework that has stood the test of time.

INTRODUCTION

Silviculture terminology that we use today was largely conceived in Europe and later adapted, modified, and expanded to meet the forestry communication needs in North America. Silviculture has its roots deep in European tradition and practice where wood production was, and still is, the driving force of forest management. As a result, terminology evolved that described the practices that eventually became the basis for most of the silvicultural systems that we know today. And that's good—we automatically have a way of communicating with our counterparts in North America, Europe, and the rest of the world.

This was recently brought home to me while visiting with colleagues in West and East Germany. Some of the language barriers that hinder communication were reduced when it became apparent in the field that "dunkelschlag" meant "shelterwood" and that "abgeholtz," "ausgeholtz," and "abtried" all referred to some aspect of clearcutting. Sure, the words sound a lot different, but the meaning is the same—shelterwoods and clearcuts by any other name are still shelterwoods and clearcuts.

HISTORICAL BACKGROUND OF FORESTRY TERMINOLOGY IN NORTH AMERICA

Our predecessors in North America saw the need to communicate using some sort of uniform terminology. Already in 1905 "Terms Used in Forestry and Logging" was prepared and published by the Society of American Foresters (SAF) and the U.S. Department of Agriculture (Fernow 1905). It served its purpose for the time, but the SAF felt it needed improvement so a committee under the leadership of Fernow published an updated glossary of forestry terminology in 1917 and 1918 (SAF 1917, 1918).

The Fernow glossary was most adequate until 1938 when an updating was in order, so Korstian appointed an SAF committee to do just that. In typical forestry fashion the committee got right on it and published the new version in 1944 (SAF 1944). The delay was likely due to World War II when many of the people had other things to do. Substantial additions were made at this time because the scope of forestry was changing. Some of the older terms had become obsolete and forestry practices had become more specialized. It was a substantial effort and included the use of 10 subject-matter subcommittees under the leadership of Hawley. This "Forestry Terminology" publication was popular and copies of it were soon exhausted. So another collating committee was appointed and a second edition that updated and revised the 1944 version was published in 1950 (SAF 1950). This version made the first fledgling steps toward incorporating mutually worded definitions of British and North American forestry terms.

Increasing levels of acceptance of the forestry terminology resulted in fewer changes needed when the third edition was revised and published in 1958 (SAF 1958) after the supplies of the 1950 version were exhausted.

As the need to communicate internationally increased, several international organizations realized that forestry terminologies should be expanded to accommodate the world of forestry. The Food and Agriculture Organization (FAO) of the United Nations was asked to do this

by the Third World Forestry Congress held in Finland in 1949. Things did not move too fast on this because of inadequate funding and a higher priority need of developing an internationally accepted subject matter classification for forestry. Eventually though, the United States and Canadian governments provided funds that were channeled through the SAF and served as the major catalyst in getting an English language version of terminology published in 1971 (SAF 1971). Similar versions were also undertaken in German, French, and Spanish. Many well-known people in American forestry such as Harper, Jemison, Clepper, Glascock, and Meyer were involved with the organizational and technical aspects of publishing the 1971 book. This comprehensive document served the forestry community well, but it soon needed updating. An addendum was included with a reprinting of the terminology in 1983 (SAF 1983). Thus, we see that forestry terminology, as with language in general, is a dynamic process. Interestingly, we've seen few substantive changes in silvicultural systems terminology for many years.

SOME DEFINITIONS OF SILVICULTURE

A silvicultural system from a researcher's perspective is, we hope, the same as that for the practitioner. It is perhaps most aptly defined in the most recently published version of the "Silvicultural Systems for the Major Forest Types of the United States" (USDA 1983) as "a process whereby forests are tended, harvested, and replaced, resulting in a forest of distinctive form. Systems are classified according to the method of carrying out the fellings that remove the mature crop with a view to regeneration and according to the type of forest thereby produced." For example, a shelterwood cutting has such a profound influence on the present stand and the establishment, character, and development of a subsequent stand that the term is used to describe the silvicultural system.

Most forestry texts define silvicultural system in much the same manner but vary somewhat in having slightly different or more limited terms. For example, some describe silvicultural systems in a more limited scope, restricting them to harvest cutting and regeneration processes only and not including the tending of the subsequent stand.

Not everyone sees the need to be overly concerned about silviculture terminology while others will call you on the carpet for even small deviations from the "accepted" terminology. Silvicultural terms are frequently butchered by those in other disciplines attempting to describe a sanitation, weeding, or other silvicultural practice in terms not wholly acceptable to silviculturists.

In light of the growing and broadening expectations of silviculture I firmly believe that we must expand the definition of silviculture in North America. I believe that: *Silviculture is the science and art of managing forests to meet resource needs. No matter the resource or management objective—be it esthetics, water, timber, wildlife, or recreation—silvicultural practices are the driving force, the means used to achieve the desired end.* This requires the use of appropriate silvicultural systems that manipulate the forest in a manner consistent with management objectives.

At this time, silviculture is truly both a science and an art, but we will be able to gradually rely more on the science of silviculture as the knowledge base increases for our forest ecosystems. Some of these increases in knowledge may well require expansion and revision of silviculture terminology, but we must resist the urge to create new terminologies for silvicultural practices that are already well-defined and accepted.

SILVICULTURAL SYSTEMS FROM A RESEARCH PERSPECTIVE

Most research silviculturists look favorably on a systematic approach to silviculture terminology. System by its own definition implies a sense of order. An orderly process enhances the opportunities for the researcher to capitalize on factors that increase the value of the research. These factors include:

1. Stratifiable—Most silvicultural research aims at evaluating results of tests over a wide spectrum of stand (and other) conditions. Presently accepted silvicultural systems provide the gradients and stratifications needed for these types of evaluations. For example, clearcut, seed tree, and shelterwoods provide a stepwise gradient of harvest level, shade, seed production, species composition, and other factors that permit evaluations of regeneration processes, reserve stand growth, subsequent stand development, water use, understory development, and other resource values.

2. Identifiable—To make research results effective, studies should be done in a framework that is meaningful to the practitioner and to other scientists. The terminology should be mutually understandable. Unfortunately, we probably all know of studies conducted in the forest that were not within any identifiable silvicultural system. These studies have usually involved protection objectives, such as entomology and fire, or nontimber resource objectives. Too often, conclusions drawn are short-sighted or impractical and some even fall into the

realm of "curing the illness but killing the patient" because they were not done within the context of a viable silvicultural method. Sometimes they solve the immediate problem but create a long-term management problem.

3. **Communicable**—Most silvicultural research is of an applied nature that relies on some of the basic forestry classifications to interpret, interpolate, and extrapolate. Silvicultural systems provide the benchmarks needed by the researcher to communicate to the user. The most effective communication must be able to cross the barriers of time and space. What was done 50 years ago should be as understandable to the user as if it were done this year. What is done in one location should be able to be related to work done in other locations, even though the locations may be miles apart, when due consideration is given to ecological conditions of the area.

4. **Repeatable**—The validity of research increases when studies provide repeatable results. To do this, the framework or design of the studies must be essentially the same. Silvicultural systems provide that framework.

5. **Quantifiable**—To be most meaningful, many of the research results must be quantifiable. Without a rational framework to stratify conditions, quantification can become a nightmare of variation that defies meaningful interpretation and application.

6. **Credible—Credibility** is nearly always increased when systematic approaches are taken in any discipline. One of the ways of increasing the credibility of silvicultural research is to couch it within describable and repeatable silvicultural systems.

SUMMARY

By now, you have likely surmised that I am a strong supporter of the use of silvicultural systems as a framework for research. And this is true whether the objectives are timber, water, wildlife, esthetics, or other resources. We must be careful about cluttering silviculture terminology with vogue-type descriptors for silvicultural practices that already have well-defined terms. We do not need to "re-invent the wheel" of silviculture terminology. Thus, I feel we must be cautious about undue revisions. As the current saying goes: "If it works, don't fix it." That does not mean to say that we should not be looking at ways of adding to the system in a hierarchical fashion. As new research results and practices become available, they should be added. This will be particularly true in North American silviculture where we are looking at the broader definitions of silviculture needed to describe those systems that also aim at enhancing nontimber resources such as water, wildlife, and recreation as well as those systems needed to better protect forests from pests and fire with silvicultural manipulations. Terminology should reflect growth and change, but it should also strive for stability. What we have now has stood the test of time quite well—let's use it, improve it, preserve it.

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ALTERNATIVE SILVICULTURAL SYSTEMS - WEST

Challenges and Opportunities

by

Peggy Kain
Newport District Ranger
Colville National Forest¹

INTRODUCTION

The theme of this conference "Silvicultural Challenges and Opportunities" is very pertinent to the forest management climate of today and into future in the Northwest.

Major challenges I see silviculturists wrestling with include:

1. Incorporating the wants of the owners of our National Forests into our strategies and prescriptions for management.
2. Prescribing to meet a variety of resource objectives, with production of timber being only one of many.
3. To accomplish the above challenges while maintaining healthy, viable forests.

The Forest Service is no longer the accepted authority on forest management we once were. We are challenged to meet the resource objectives we have identified, plus those identified by a diverse, and involved public. Often the objectives identified by the public are value judgments that conflict with our preferred biological solutions. These groups and individuals who are challenging our decisions are definitely impacting our choices of management options.

The Draft Forest Plan on the Colville Forest prescribed even-aged silvicultural systems for all managed lands. Overwhelming public response from industry, environmental organizations and individuals that favored uneven-aged management techniques was incorporated into the Final Plan which calls for individual tree or group selection methods in all visually sensitive areas, and all priority recreation areas. A number of other R6 Plans now between draft and final will recommend uneven-aged silvicultural alternatives be considered as viable tools that

can be used by silviculturists when prescribing to meet management objectives.

The opportunities ahead of us as silviculturists and land managers include broadening our scope of thinking to include tools (alternatives) we presently have little familiarity with, and demonstrating that careful application of a variety of silvicultural techniques will allow us to meet a variety of resource objectives, while still maintaining the health and vigor of the stands.

A point in our favor in attempting to meet various objectives is that most of the tree species we manage can be established and will grow at an acceptable rate under a variety of ecological circumstances. Often factors such as economics, roading restrictions, and management objectives are the determining factors in selecting a particular prescription, rather than maximizing growth and yields.

WHERE WE HAVE BEEN

A silviculturists job in past years was often one of prescribing to maximize timber outputs while mitigating impacts to "other resources" (as we called them), such as water quality, wildlife and fisheries habitats, recreational values, and range needs. We were given specific direction that emphasized even-aged systems for the purpose of minimizing costs of harvest and regeneration, and maximizing timber outputs from a given acre over time. Cutting "decadent" stands was a positive objective because it allowed for replacement of those slow growers with stands that had a greater potential to fully use site potential to grow fiber; A very different objective than what we face now with old growth issues. As a general rule we were and are commodity oriented. The most often used silvicultural alternatives prescribed to meet our growth and yield objectives include clearcut-

¹ Presented at the National Silviculture Workshop, Petersburg, Alaska, July 10-13, 1989.

ting, shelterwood, seed tree, commercial thinning, and overstory removal.

WHERE WE ARE TODAY

As in the past, today we are prescribing to produce fiber and boards. At the same time, we are called to manage many resources with an equal amount of energy, which often can force us out of the familiar prescription alternatives and what we might consider to be better biological solutions and into areas where there has been less research and where we have more questions than there are answers. It is not uncommon today for a silviculturist to prepare a prescription where timber outputs are secondary, or a result of managing for wildlife and fisheries habitat, specific range conditions, recreation values, or riparian habitat drive the primary objectives of the prescription.

In order to respond to the types of management objectives I've just mentioned silviculturists must be even more creative and flexible in planning and implementing treatments. We must be willing to try management schemes that are new to us and accept less than hoped for results as we learn. We must be able to listen and communicate with "ologists", specialists, researchers, and the public to visualize a picture of the desired future condition and evaluate and prescribe vegetation management options to achieve that desired future state. Silvicultural terms such as group shelterwood, free selection, free thinning, strip shelterwood, strip clearcut, continuous forest, reserve tree shelterwood, and selection thinning are becoming more frequently used parts of our vocabulary and alternative options. Our terminology may also need to be adjusted to include terms that measure resource outputs as well as timber production.

FACTORS TO CONSIDER DURING SILVICULTURAL ALTERNATIVE DEVELOPMENT

CONSIDER - What vegetative diversity of the overstory and understory is necessary to meet the identified objectives, and at the same time maintain the health and vigor of the forest being managed. Focus on managing ecosystems rather than stands of trees. Requires an understanding of the interactions within the ecosystems and also the resource needs and objectives identified during the planning process.

Example - Selecting a prescription that maximizes resprouting and growth of huckleberry for use by big game and huckleberry pickers in a heavily used picking area. Accepted less than optimal site prep for tree planting in order to accomplish the overriding objective, and planted fewer trees per acre than would otherwise have been prescribed.

CONSIDER - The need to plan for management of all resources in an integrated manner over space and time, (IRA) in R6. The silviculture prescription is one of the foundation blocks for this process.

Example - Colville Plan MA 6 (Scenic Winter Range). Combines even-aged and uneven-aged systems to meet retention and partial retention visual objectives with a maximum even-aged unit size of 20 acres in unseen areas to meet forage and edge requirements.

CONSIDER - A watershed or viewshed perspective, incorporated with a knowledge of stand dynamics, in order to measure effects from, and balance of, resource management practices in an integrated manner.

Example - The effects of intermingled ownership with timber companies has complicated planning efforts. Management practices on company land determines to some extent what latitude we have to manage National Forest lands when considering cumulative impacts to wildlife habitat and water quality, and assessing what is or isn't an acceptable visual impact.

CONSIDER - The need to have a more finite understanding of the silvics of species in our localities in order to maintain viable stand diversity and health, when using uneven-aged systems.

Example - How big an opening (group selection area) is needed to regenerate and maintain Douglas-fir, Western Larch, or White Pine in habitat types that include substantial components of Western Hemlock, Western Red Cedar and Grand Fir? We don't know the answers now, but we will be experimenting on a site specific basis.

CONSIDER - What are the possible or probable outcomes of uneven-aged management scenarios over time, frequent entries causing compaction and injuries to residual crop trees, ability to manage impacts from insects and disease.

Example - In stands that have been entered 2 or 3 times in the last 40+ years with tractor systems over 50% of the Western Hemlock residuals are cull as a result of scarring from past yarding practices.

CONSIDER - Understanding of the characteristics that constitute old growth so that some of those characteristics can be produced and maintained over space and time.

Example - There seems to be more research and a clearer understanding of some of the components of old growth ecosystems in the Douglas-fir region than presently exists for the pine and mixed conifer ecosystems of the

Inland Northwest. We just don't know how much down woody debris should be left on site, or how many snags to leave, or how many canopy layers will provide the habitat characteristics.

CONSIDER - The complexities of riparian management. Are the basic objectives, driven by watershed protection, water quality, fisheries or wildlife habitat requirements, hydro-power needs or timber harvest? This question must be answered in order to design a system for management.

Example - Protection of downstream domestic water sources or municipal watersheds will require much more restrictive management practices to limit sedimentation than when managing the riparian area of a Class IV intermittent with no water source or fisheries downstream.

CONSIDER - How do we balance the need to manage for high value timber with the need to meet other resource objectives.

Example - Managing to meet visual or watershed needs using small openings or uneven-aged systems will favor shade tolerant species which often times are lower valued than many of the shade intolerant species.

CONSIDER - Continue futuring efforts to evaluate changes on the horizon in product demands of National Forest resources; High value wood products, recreation opportunities, wildlife and fisheries enjoyment etc.

Example - As the demand for outdoor recreation increases the need to create and maintain developed and dispersed sites for their use requires complex vegetative management prescriptions and close coordination with users.

CONSIDER - The balance of natural regeneration and the emphasis to grow genetically improved stock.

Example - We have emphasized use of natural regeneration for the purpose of controlling reforestation costs. Planting and interplanting genetically improved stock is prescribed to capture the increased growth programmed into the ASQ for the 10 year planning period of the Forest Plan.

CONSIDER - The challenge of accomplishing regeneration of sites with limited use of fire and herbicides as tools.

Example - As smoke management restrictions reduce our window of opportunity to burn slash there is increased attention on planting through slash, yarding with tops attached, and chipping landing slash and blowing chips onto the units.

CONSIDER - The impacts of current management practices on long term site productivity, shortened rotations, periodic soil disturbance, compaction and displacement, amount of woody debris left on the site, and better utilization.

Example - Prescriptions call for leaving large down logs and protecting them during burning. Cooler broadcast burns leave the duff layer and more of the greater than 3 inch material.

CONSIDER - The need for information sharing among silviculturists and research personnel in order to answer many of the questions concerning wildlife habitat needs, uneven-aged management alternatives and effects, and long term site productivity needs.

Example - Region 6 is just beginning a coordinated effort between the Research Branch, the National Forests, and BLM to conduct long term site productivity studies to begin answering many of our questions. The cooperation of researchers and operations people is essential for this project to be successful.

This is a most exciting time to be a silviculturist in our organization, but also the most frustrating. There will be few answers to many frustrating questions, and many of the questions are not silvicultural in nature. The opportunity exists to try management techniques that haven't been used extensively in the past, and it must be accepted that not all attempts will be successful as we try new techniques to meet the demands placed on the resources we manage. This is a time to continue to broaden our knowledge base, with a greater than ever need to share information and successes and failures with our colleagues. Our charge is to accomplish the objectives identified in our planning processes, while at the same time maintaining the health and vigor of the forests environments in our charge.

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ALTERNATIVE SILVICULTURAL SYSTEMS—WEST

A Perspective from the Douglas-fir Region

Dean S. DeBell
Principal Silviculturist
USDA Forest Service
Pacific Northwest Research Station
Olympia, Washington¹

INTRODUCTION

There are many reasons to consider alternative approaches to forest management in the West, but the primary stimulus for such consideration in the Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) region has been the continuing conflict over harvest of the remaining old growth. This controversy is being played out with focus on the northern spotted owl (*Strix occidentalis*) – its candidacy as a threatened species and the consequent concerns over future harvest levels and the health of the region's timber-based economy. Some managers and scientists have viewed alternative silvicultural systems as a possible solution to conflicts over many other land use and allocation issues. Several terms have been used to label the concepts; in addition to alternative silvicultural systems, we have heard "new forestry," "new silviculture," "ecological forestry," and "sloppy logging." One of my colleagues refers to a "kinder and gentler" forestry. Although none of these terms seems fully satisfactory, all the discussions have centered on the development and evaluation of silvicultural techniques and landscape-level strategies for multipurpose forest management. In essence, the proposed systems offer alternatives to the standard practice of clearcutting in dispersed patches, slash burning, and planting Douglas-fir; and they place added emphasis on managing forests for diverse values. In addition to the commonly recognized multiple uses, such values include preservation of biological diversity, maintenance and enhancement of site productivity, maintenance of forest health, improved stability and hydrologic functioning of the forest, and increased social acceptability of timber production on forest lands.

The proposed practices are still in the formative, conceptual stage; they have been influenced by personal values and strategies for dealing with land management conflicts as well as by scientific theory and experimen-

tal data. My presentation therefore will consist primarily of a report on ideas generated by many individuals throughout the Douglas-fir region blended with some personal opinion. I have organized my remarks in the following order: the setting, proposed methods, desired results, and lastly, some closing comments that include suggestions on ways to develop and evaluate some alternative management systems. The examples will come from the Douglas-fir region, with emphasis on timber-wildlife considerations for National Forest lands.

THE SETTING—WHERE WE ARE

Major changes have occurred in the development of National Forest lands during the past 30 years. In many drainages, the forest landscape has changed from extensive stands of old growth or mature second growth to a mosaic of 20- to 60-acre patches, formed by islands of the original older age classes and much younger stands, generally from 1 to 40 years old. Thirty years ago, the young, seral stages of forest succession and edge environments were relatively scarce in many drainages; such habitats increased as older stands were harvested, and populations of wildlife species associated with these environments also increased. Today, the habitats of concern to many wildlife specialists are those associated with old growth, where interior forest species such as the northern spotted owl, pine marten (*Martes americana*), and red tree vole (*Phenacomys longicaudus*) find their optimal environment.

There is a marked contrast between the knowledge base for timber production and that available for management of forest lands for most other products and values. For more than half a century, silviculturists have had timber inventory data, growth and yield tables for unmanaged stands of young-growth Douglas-fir, some general principles for developing stand management strate-

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gies, and a fair understanding of habitat requirements and other silvical characteristics for Douglas-fir and associated tree species. Wildlife biologists today, though, have a level of understanding that seems more or less equivalent to that available several decades ago for timber management in the region. Much of the existing information on wildlife in *managed* forests concerns either game species, such as elk (*Cervus elaphus*), deer (*Odocoileus* spp.), and ruffed grouse (*Bonasa umbellus*), or species that have caused extensive damage to forest plantations, such as mountain beaver (*Aplodontia rufa*) and pocket gopher (*Thomomys* spp.). Current knowledge for most other species comes primarily from *unmanaged* stands of old growth and stands of young growth that have received little or no management. Little research has been done on habitat relations and other characteristics of nongame and non-pest species in *intensively managed* forests of the Douglas-fir region. Knowledge pertaining to other uses and values, biodiversity, and changing climate is even more limited.

The sociopolitical environment is also changing—perhaps recent changes have been greater in the Douglas-fir region than elsewhere in the country. In addition to requirements of Federal legislation (National Environmental Policy Act, National Forest Management Act, Endangered Species Act), our silvicultural practices have been restricted by state laws, regional court decisions, and regulations issued by state agencies; moreover, our forests are highly valued by a broad spectrum of interest groups, so that forest practices are closely scrutinized. Forest management conflicts have become increasingly polarized between some who view the forests primarily as a source of raw material necessary for jobs and economic development, and some who would prefer to have forests treated as national parks. Between these extremes is the majority of people and groups who hold more moderate views. Their views are commonly expressed in comments submitted on National Forest plans, but they seem to receive little attention in the media and courts. The future of multiple-use forest management may hinge on the activity of the moderate majority and the extent to which their actions are felt throughout the region.

The setting therefore includes (1) continuing conversion of older, unmanaged forests to a managed state; (2) scarcity of information about effects of management on some forest uses and values; and (3) increasing conflict over forestry practices and uses of forest lands. These seem to be good reasons to consider alternative approaches to forest management, and thus, there is interest in developing practices that may be useful, perhaps even essential, for sustaining various populations of animal and plant species.

PROPOSED METHODS—SILVICULTURAL PRACTICES AND STRATEGIES

The alternative silviculture proposals are complementary to the current package of silvicultural tools; they provide additional options or modifications of existing options, and they may benefit timber as well as non-timber uses and values. Some silviculturists and other people who have been concerned primarily with timber production seem to view them as additional restrictions on the practice of “sound forestry”, but this is a mistaken notion. It exists in part because their interests focus on wood production and possible reductions in current harvest levels, and also because *laissez faire* management and natural regeneration are sometimes mentioned in such proposals. Both ideas—that sound forestry will be restricted or that *laissez faire* management is desirable—are based primarily on ideology. Opportunities to manipulate and enhance productivity of forest lands through use of genetic tree improvement, vegetation management, stocking control, and nutrient amendments need not be foregone by adopting most of these proposals. Exact prescriptions may be modified to benefit a non-timber use or provide some optimal mix of products and values, but silvicultural knowledge will simply be applied to meet a wider spectrum of management objectives.

The alternative silviculture proposals involve considerations at two scales: (1) silvicultural practices at the stand level, and (2) strategies for regulating management activities in time and space within large drainages or landscapes. The latter scale is sometimes referred to as landscape ecology; it differs little in basic concept from what foresters have long referred to as forest management and forest regulation. The objectives and concerns are currently much broader, however, than those considered in the past. I will describe some of the options proposed for evaluation in the Douglas-fir region.

Stand-Level Practices

The alternatives at the stand level involve modifications in species composition, stand structure, rotation length, and “carryover” of selected components of old-growth and mature forests to the new stand.

Species composition—Interest has increased in establishing or retaining other species (that is, species in addition to Douglas-fir) in pure and mixed stands in our managed forests. The objectives are many, and they range from solutions for specific site problems (for example, root rot or low soil nitrogen) to providing more diverse habitat for wildlife.

Red alder (*Alnus rubra* Bong.) stands, for example, may be planted on lands severely infested with laminated root rot (*Phellinus weirii*) of Douglas-fir. The root-rot problem is extensive in northwestern Oregon and seems to be increasingly recognized elsewhere. Growing an alder crop in rotation with Douglas-fir also provides an opportunity for increasing soil nitrogen levels, which presently limit productivity on more than two-thirds of Douglas-fir sites. Alder management recently has become more attractive because regional markets for solid wood have expanded and a worldwide market for pulp of short-fibered species has developed.

Now that blister-rust resistant stock is available, western white pine (*Pinus monticola* Dougl. ex D. Don) merits consideration for increased planting throughout the region. White pine has high economic value, is adapted to a variety of sites, and has rapid juvenile growth rate.

Various mixtures of western redcedar (*Thuja plicata* Donn ex D. Don), red alder, and Douglas-fir have been proposed to meet certain goals. The interplanting of red alder with Douglas-fir at Wind River Experimental Forest in the Gifford Pinchot National Forest (southern Washington) is a classic example of potential opportunities; nearly one-half century after planting, heights of dominant Douglas-fir grown with interplanted alder were taller than those in an adjoining pure Douglas-fir stand by the equivalent of one full site class. Volume of Douglas-fir in the mixed plantation equaled that in the pure stand, but it occurred on fewer, larger stems and hence had greater value. Total volume of Douglas-fir and alder in the mixed stand was double that of the surrounding pure Douglas-fir stand. Soil under the mixed stand contained about 1000 pounds of nitrogen per acre more than soil under the adjoining pure Douglas-fir stand. Mixtures of western redcedar and Douglas-fir have been suggested for several purposes: a hedge against root-rot problems, "trainers" to encourage self-pruning of wider spaced Douglas-fir, acceleration of canopy differentiation, and increased structural diversity. Red alder and western redcedar provide a mixture that theoretically seems ideal with regard to growth patterns, shade tolerance, and nutrient cycling. Both species can be grown on sites too wet for successful production of Douglas-fir.

Stand structure—Additional approaches proposed for providing greater diversity in stand structure include two-storied, two-aged stands and extremely wide spacings. Objectives include providing trees suitable for certain uses by wildlife and increasing growth of forage species in the understory.

Two-storied, two-aged stands can be developed by retaining some portion of the overstory trees (perhaps 10

to 20 percent) when vigorous, mature stands are harvested. These reserve trees can supply added structural diversity to meet wildlife needs as well as provide an eventual source of large snags and down trees. Such objectives may be enhanced by topping the trees by saw or with dynamite, and snag formation can be manipulated by using any of several means to kill trees on some schedule. From a timber standpoint, such retention may also offer an opportunity to produce some larger, older trees with higher quality wood characteristics on sites managed on a much shorter rotation. We do not know how many such trees need be left or how they should be distributed to best meet multiple objectives, and considerable time and effort will be needed to develop such information. It should be relatively easy, however, to assess "response" of the mature trees to their changed environment and evaluate effects of the reserved trees on establishment and growth of various components (planted or natural) of the new stand. This approach is, of course, not appropriate in most old-growth stands and in other stands where the residual trees will be susceptible to windthrow, and it is unsuitable for use in stands infested with dwarf mistletoe (*Arceuthobium* spp.).

The second approach to modifying stand structure entails planting or thinning at very wide spacings and may involve relations between overstory and understory components. Wide spacings have recently generated considerable interest in the region; coupled with pruning, they offer the possibility to greatly shorten the time needed to produce large-diameter, high-quality logs. Although the current interest is associated mostly with timber production, such regimes also provide opportunities for maintaining—perhaps even manipulating—understory broadleaved trees and shrubs as well as herbaceous species over a much longer period than is possible at conventional, denser spacings. Wildlife and soil productivity could benefit from such management of the understory (for example, by using *Ceanothus* spp.). In addition, wide spacings may be beneficial for livestock grazing, a use receiving increased consideration in some parts of the region.

Elsewhere in the West, there is a reawakening of interest in uneven-aged management and selection systems. Forest managers and scientists have not proposed such practices for general use in Douglas-fir stands because of limitations associated with ecological characteristics of the species and concerns related to topography and soils. Such systems, however, may have a place in coastal hemlock forests and in upper slope, mixed-conifer forests, provided that topography and soil conditions do not restrict harvesting operations.

Rotation length—The short rotations now popular on some forest ownerships are based primarily on calcu-

lations of net present worth and obviously will involve some reduction in volume yield. On National Forests, rotations are generally set to approximate culmination of mean annual increment of stem wood, but this seems a bit simplistic in view of our multiple objectives and concerns. This is recognized in current decisions to delay harvest of some trees on some sites far beyond the time of culmination of stem increment. It might be useful, though, to think of this "peak in mean accretion" in terms of a wider range of products and values. As we develop and evaluate alternative approaches to silviculture, we should also conduct a new and more comprehensive assessment of relations among rotation length, volume and value production, and associated economic, ecological, and sociopolitical considerations. When all costs, benefits, and strategies of forest management are fully considered, there may be good reasons for rotations either longer or shorter than those now planned. And they may differ substantially from site to site or among different objectives for the same species; for example, soil-improving benefits of red alder may peak before to culmination of mean annual stem increment, whereas optimal conditions for some wildlife species or recreational values may culminate much later in the life of such stands.

Unmerchantable remnants of existing stands—Most old-growth and many mature second-growth stands contain snags and down trees, many of which could be retained to provide what has been termed a "biological legacy" for the next rotation. Although it is relatively easy to retain such remnants by modifying harvest and site-preparation practices, there are many questions about the quantity and distribution appropriate for various wildlife objectives or other values. Such retention is already practiced to varying degrees on public ownerships, and tests are underway in some experimental forests to evaluate effects. Combining selective retention of green trees, snags, and down trees with initial wide spacing of planted stock (and perhaps other practices aimed at enhancing growth rate) may offer an accelerated pathway to certain "old-growth conditions" in young managed forests.

Landscape-Level Strategies

Many of the major issues facing National Forest managers—biological diversity, threatened and endangered species, fish and wildlife habitat, and cumulative watershed effects—occur at the drainage level and require sound landscape management practices. Some of the decisions and questions involve size and distribution of old-growth stands to be retained and size, shape, and distribution of cutting units (and hence, future stands); cutting patterns that minimize fragmentation of the remaining old-growth forests offer an alternative to the

dispersed patch (or staggered setting) clearcutting that has been the norm in National Forests of the Douglas-fir region. Other matters of concern include the juxtaposition of various vegetative types and stages (for example, hiding cover, thermal cover, and feeding areas for elk or deer), maintenance of corridors between islands of old growth or other patches—managed or unmanaged—devoted to specific objectives, and management of riparian zones. Prescriptions for some of these considerations are, at present, best guesses; others might be characterized as second or third approximations—all can benefit from further assessment and refinement.

Scientists and managers may debate various approaches at both the stand and landscape levels, but the scientific evidence for preferring or concentrating on any one of them—even for a single objective—seems rather limited. Given our current state of knowledge and present forest conditions, I think that a mix of approaches—coupled with appropriate research and monitoring efforts—would be prudent and perhaps the most beneficial for multipurpose forestry.

EXPECTED RESULTS—DESIRED OUTCOMES

The incentives for implementing some or all the practices and strategies I've described include (1) depolarization of positions held by various groups on use of public forests, and (2) enhancement of forest conditions and productivity for many values and uses. Expectations for attaining such results are now quite high in the Douglas-fir region. As we proceed, however, I think we will need to maintain a degree of caution appropriate to the conceptual stage of the proposals. This need for caution is related more to the risk of strongly advocating or doing some "useless stuff" than to causing any major, long-term harm. Even so, doing "useless stuff" may damage our credibility as forest managers and scientists and also can waste human and financial resources that could otherwise be spent on more beneficial activities. We also will need to maintain a strong commitment to supportive programs of monitoring and research.

Depolarization of Positions

Some "strategists" believe that development and application of more diversified forest management systems will help bring about the consensus needed to proceed effectively with management of publicly owned forests. I too have this hope; however, I suspect that success in this regard will hinge on greater involvement of a larger segment of our citizenry—the less visible and more moderate majority. Such participation can be influenced through the educational efforts of public agencies, as well as by the behavior of groups at the ex-

tremes. Trends toward success or failure in attaining the "depolarization" objective will be identified long before we can determine biological and economic impacts of newly implemented practices. An indication of the possibilities is the recent success of the State of Washington Department of Natural Resources in achieving consensus on a package of recommendations from a Citizens Commission on Old Growth Alternatives. Proposed practices and strategies similar to those previously discussed—including establishment of a 250,000-thousand-acre experimental forest—were significant factors in this agreement. The commission process and the consensus achieved place the Department of Natural Resources in an excellent position to meet challenges from individuals or groups who may disagree with the resulting management decisions and activities on the western Olympic Peninsula.

Improved Multipurpose Forest Management

The degree to which the condition and productivity of forests is enhanced will require much longer to evaluate, and—to a large degree—the answer will depend on the objectives of management. Defining the basic objectives for managing various landscapes is a major task, because choices will differ with the characteristics and desires of human populations as well as properties of various ecosystems, even within the same National Forest. Although reasonable hypotheses do form the bases for practices proposed to meet diverse objectives, there is much to be learned in our quest for improved systems. Needed information can be classified in three broad categories:

1. Identify tree, stand, and forest characteristics that are essential or desirable for preservation and production of various values and products. Although much information is available for timber production, data for most other management objectives or combinations of objectives are limited.
2. Silvicultural approaches to develop or retain desirable features—in both time and space—at the stand and landscape level.
3. Evaluate the costs and benefits, biological and economic, associated with various practices and strategies. Only then can we develop useful procedures for decision-making and long-term planning.

These categories of information are sequential in the decisionmaking process. Research and development can proceed more or less simultaneously for all categories, though. Each research study or pilot-scale trial of a new or modified practice can provide added data for examining relations between stand or landscape

characteristics and various forest conditions or products. Such information may also yield insights into practices likely to provide the most desired attributes. At the same time, a data bank of costs and benefits can be accumulated.

CLOSING THOUGHTS

Some members of the forestry profession have suggested that the "golden age of silviculture" in the Douglas-fir region occurred during the 1970s. This may be true if one equates the golden age to a time when large amounts of money were spent on intensive practices related solely to timber production. But if one views silviculture in its broadest sense—the manipulation of forest vegetation for any and all purposes, then the golden age may just be dawning. For many years, timber harvesting enhanced other forest uses; deer and elk populations increased and roads improved public access to the forest for various recreational activities. Although this may have been fortuitous initially, it came to be recognized and appreciated by forest managers and forest users. In the last decade, however, our forests and scientific understanding have reached stages in their development where it is appropriate to develop silvicultural systems purposely meeting a wider range of forest management objectives.

This task of developing and refining such systems for multiple-use forestry and providing the scientific bases to make intelligent choices among alternative approaches is a large one, and it will be a costly one. To provide the kind of information needed, research and management will have to work together. Such cooperation is especially necessary for landscape-level considerations, which will be difficult, if not impossible, to approach via conventional research methods. Cooperative programs that pool financial and human resources from management and research organizations seem essential. They must provide for long-term and large-scale assessments, and they must ensure linkages among basic research, applied studies, modeling efforts, monitoring, and transfer and application of technology.

The immediate need is to integrate silvicultural technology with developing knowledge from other disciplines in the design of management systems that provide a greater mix of products and conditions. Although this will require some modification of practices developed for intensive timber production, it does not mean that these practices should be abandoned. Their role, in fact, will become even more important on lands where timber production remains a dominant use, and they may also be useful on lands managed for broad or multiple objectives. For example, it may be desirable to preserve

snags, retain a small component of mature green trees, *and* plant genetically-improved stock, *and* enhance nutrient status by application of fertilizer on the same site or cutting unit.

Silviculturists in the Douglas-fir region are searching for ways to mesh their skills with those of other specialists in the development of new approaches for multipurpose forestry. In this manner, we intend to provide more varied benefits for more people and also retain some flexibility to meet changing needs and desires of future generations.

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Alternative Silvicultural Systems in the Eastern Region

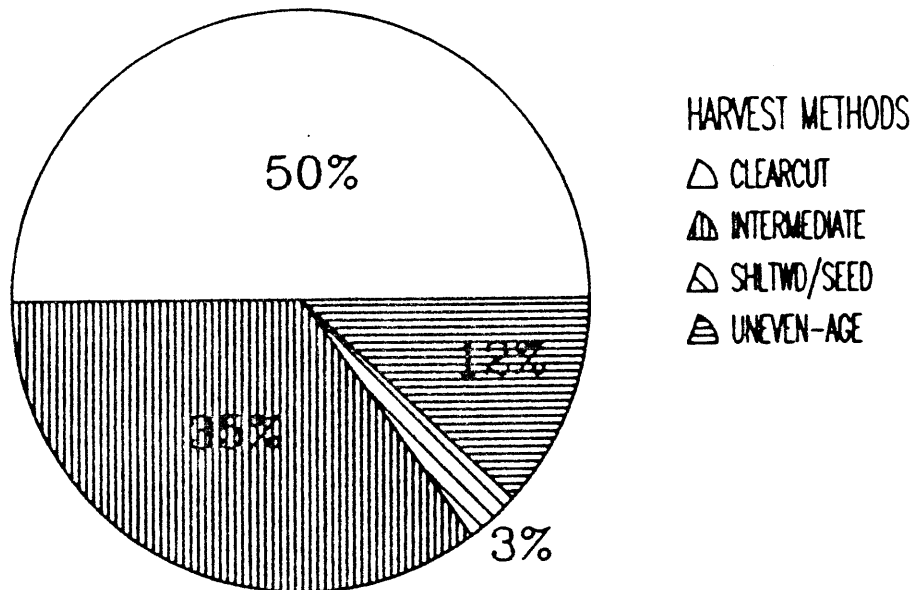
Mike Lanasa
Forest Silviculturist
Hiawatha National Forest

The Eastern Region covers the 20 state area from Maine to Minnesota and from Maryland to Missouri. Two characteristics of the Eastern Region influence management on the National Forests. First, public ownership is small in relation to total land area in the region. National Forests make up only 2.5% of the total area. This results in Forests being sought out by the public especially for recreational uses. Second, 109 million people, almost half of the population of the United States live in the Eastern Region. This public is very concerned with management of the National Forests as was demonstrated by the Monongahela clearcutting controversy in the early 1970's.

What kind of silviculture do we practice in R-9? Figure 1 shows our cutting methods for the last 3 years.

FIGURE 1

EASTERN REGION

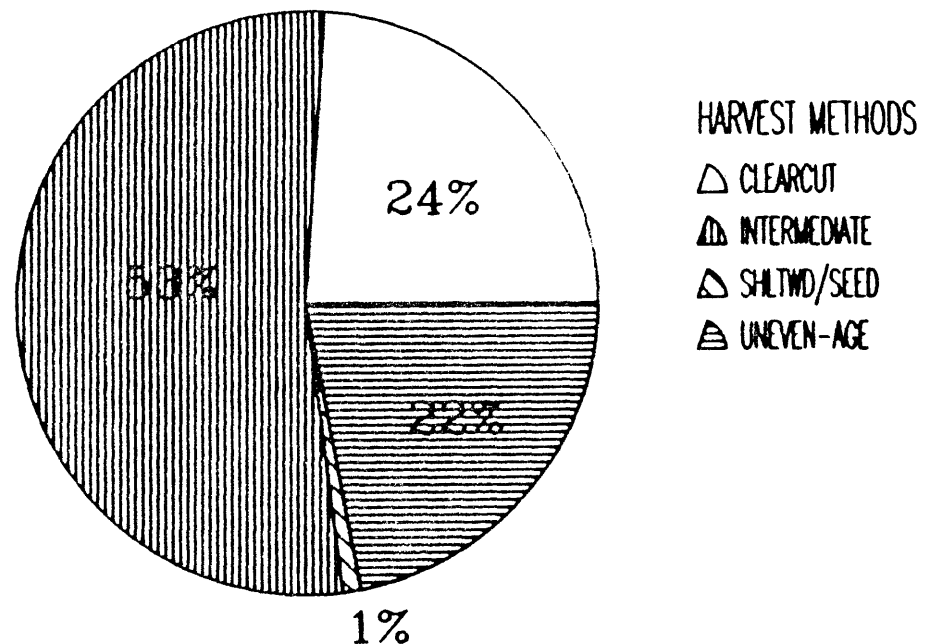


During this period 50% of our harvest acreage was clearcutting, another 35% consisted of intermediate thinnings, 3% was shelterwood and seed tree harvests, and the remaining 12% was uneven-age selection cutting.

Half of the National Forests in the Eastern Region are located in the heavily populated Lake States. The Lake States Forests have been logged over with logging activity peaking in the early 1900's. Subsequent planting by Civilian Conservation Corp, coupled with natural regeneration, have resulted in most stands being between 50 and 100 years of age. Longer lived types like the northern hardwoods or red and white pine are in need of thinning while shorter lived types like jack pine and aspen are mature and ready for regeneration. Because of glaciation and past land treatment, there is a tremendous amount of vegetative diversity present in our Forests.

I am going to be using the Hiawatha National Forest as an example of the silvicultural systems used in the Lake States. The Hiawatha is located in Michigan's Upper Peninsula between Lake Superior, Lake Michigan and Lake Huron. Silviculture practiced on the Hiawatha is fairly representative of that practiced on other Lake States Forests. Figure 2 shows our cutting methods for the last 3 years.

FIGURE 2
HIAWATHA NATIONAL FOREST



Over half of the harvesting since our Forest Plan was completed 3 years ago has been intermediate thinnings primarily in the northern hardwood type and in red and white pine stands. Approximately 24% has been clearcutting of mature intolerant forest types such as aspen and jack pine, 22% has consisted of uneven-age management; primarily single tree selection of northern hardwoods, and the remaining 1% was shelterwood and seedtree cutting.

As previously mentioned there is a lot of diversity in Lake States Forests. On the Hiawatha we have 31 different Forest Types.

Table 1, below, shows the major type groupings and the harvest methods used to regenerate them.

TABLE 1

FOREST TYPE	CC	SW	SEL	SCC	PCC
Aspen	X				
Balsam Fir	X	X	X	X	X
Black Spruce				X	X
Cedar		X		X	X
Hemlock		X	X		
Jack Pine	X				
Low. Hardwoods		X		X	X
N. Hardwoods		X	X		
Oak		X			
Paper Birch		X		X	X
Red Pine	X	X			
Spruce-Fir	X	X	X	X	X
Swamp Conifer		X		X	X
Tamarack				X	X
White Pine		X	X		

CC - Stand Clearcut

SW - Shelterwood

SEL - Single Tree Selection

SCC - Strip Clearcut

PCC - Patch Clearcut

For discussion purposes these types will be separated into 3 groupings. The first category consists of those types where clearcutting is the only recommended harvest method. These are primarily intolerant, early successional types. The second category consists of those types where clearcutting is sometimes recommended but other methods are sometimes feasible. These types vary from very tolerant to intolerant and from early to late successional types. The third category consists of those types where clearcutting is not recommended. These are very tolerant or mid tolerant, later successional or climax types.

Aspen, jack pine, black spruce and tamarack make up group 1. As previously mentioned these types are regenerated almost entirely by clearcutting. Why do we clearcut these types? Silvical characteristics are the main reason. Aspen, jack pine and tamarack are intolerant species requiring full sunlight. Black spruce though tolerant is very subject to windthrow and we use strip clearcutting to regenerate it. Jack pine in addition to being intolerant of shade also has serotinous cones that open when heated by fire or when exposed to the high temperatures that occur when cones are scattered close to the ground in open areas.

In addition to the fiber produced by these types several game species require these early successional types for habitat. Aspen is important for deer and ruffed grouse. While sharptail grouse need large openings cut in our jack pine type. Certain nongame species such as the bluebird, upland plover, and Kirtland's warbler also require early successional forest types.

Since clearcutting is necessary to manage these forest types how do we make it more acceptable to the public? First of all we manage the size of cuts. In the East, clearcuts are generally limited to 40 acres or less. Some are smaller as in the case of intensive ruffed grouse management where cuts are as small as 5 acres. Others are larger as in the case of sharptail grouse where cuts up to 300 acres in size are needed to provide needed habitat.

In visually sensitive areas we shape and design cuts to be as aesthetically pleasing as possible. Also, we leave most species such as oak, ironwood, and serviceberry; and snag and den trees for the wildlife that require them. We have been increasingly signing prominent management activities to let the public know what we are doing and why. In some situations we have been leaving residual trees in some types when these residuals were immature; partly for aesthetics and partially because the trees were immature. We sometimes felt like we were practicing some type of bastardized silviculture. Thanks to the March 1989 issue of the Journal of Forestry we now know we have been practicing deferment cutting. As Clay Smith, Neil Lamson and Gary Miller's article says, "A deferment cut looks like a seed tree cut - but you don't remove the seed trees until the first thinning or until the next stand is harvested." It has been used in Europe for quite sometime. Preliminary 5 year results from a study conducted by these authors indicate that deferment cutting has potential as an aesthetically pleasing alternative to clearcutting in eastern hardwood stands. If you have not read this article I recommend it to you - I think it has widespread application.

Group 2 is made up the balsam fir, northern-white cedar, lowland hardwoods, paper birch, red pine, spruce-fir and swamp conifer types. In this group clearcutting is one of several options used. Why do we clearcut these types? Economics plays a large part. Clearcutting and planting species like red pine at optimal spacing with it's high growth rates results in some of the most cost effective silviculture on our Forest.

Another reason for clearcutting is logging technology. We may not have any mountains but we do have wetlands where current technology requires winter logging on frozen ground. To be able to work on these sites we strip clearcut to provide access, prevent windthrow and allow natural seeding. Another reason for clearcutting is prescribed burning. Several of our types require seedbed conditions best created by fire and we are unable to burn these sites unless they have been clearcut.

I have discussed why we clearcut these types now I want to explain why we may not want to clearcut them. Red pine is a good type to use as an example. As previously mentioned clearcutting and planting red pine is very favorable from an economic standpoint. However red pine is also one of our most aesthetic types when mature. When it occurs along rivers, lakes, trails or new campgrounds, there is resistance from the public to clearcutting. In these situations we need to be able to regenerate it using an alternative method. We have scattered examples where a seed tree system has worked but we need to develop more consistent results.

Paper birch is another example. The public likes paper birch for aesthetic reasons. Stand clearcutting has resulted in hit or miss results when regenerating the type. So where we want to be sure to get paper birch back we use the shelterwood system or patch clearcutting followed by light scarification to improve our chances.

The third group of forest types consists of those where clearcutting has given us poor results and is not recommended. Why doesn't it work? Silvical characteristics is a major reason. These types are intermediate, to tolerant, to in the case of hemlock very tolerant. Since these species are adapted to shade, full sunlight resulting from clearcutting often favors faster growing intolerant species.

Another factor is insect and disease control. Clearcutting results in conditions conducive in our area to white

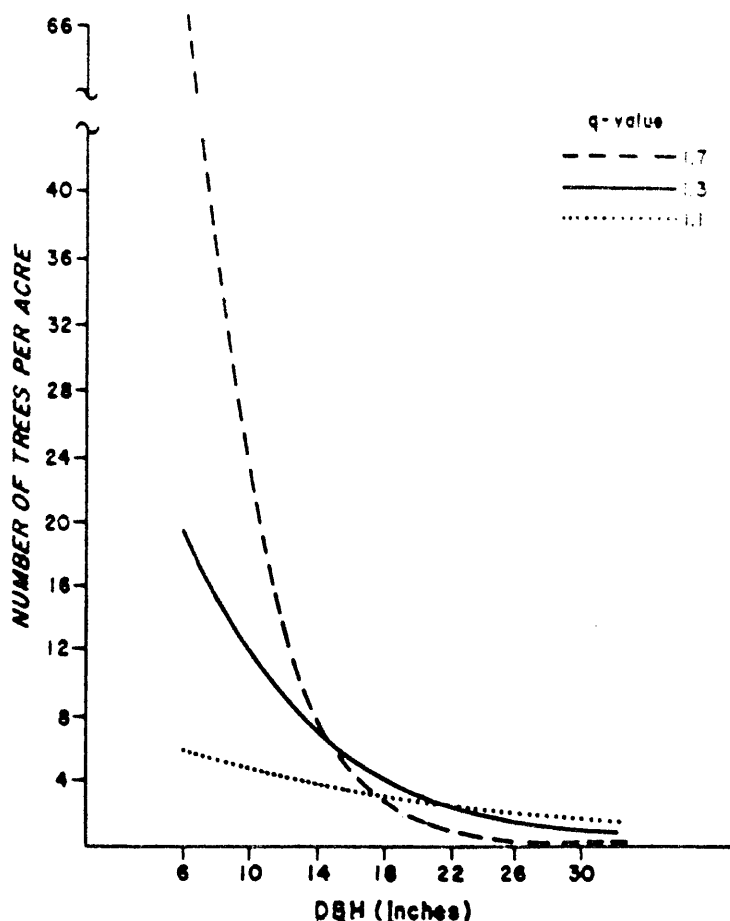
pine blister rust and white pine weevil. Through the use of shelterwood systems or single tree selection we have been able to reduce the impact of these pests and successfully manage the white pine type.

Climate is another factor that can rule out clearcutting. The Lake States receives quite a bit less rain than Central or Eastern Hardwood Forests. Whereas clearcutting works for them, clearcutting of our hardwoods generally results in brush invasion and poor stocking. We remove the overstory only if adequate regeneration is established.

Our northern hardwood type is where the majority of uneven-age management occurs on the Hiawatha. For northern hardwoods, even-age management would have to be considered our alternative system. Much of the early research on uneven-age management in the United States was done in the Lake States. For years single tree selection has been successfully practiced producing quality sawlogs and veneer. Only within the last decade has even-age management been accepted by foresters in our area. They have accepted the shelterwood system which provides good results when properly applied. As mentioned, uneven-aged management generally is used and results in stands heavy to sugar maple and beech. When less tolerant species such as yellow birch and black cherry are desired for timber or wildlife reasons the shelterwood system is used or group selection. Wildlife biologists in particular wanted some even-aged stands for the wildlife associated with sapling and pole sized hardwoods such as the chestnut sided warbler.

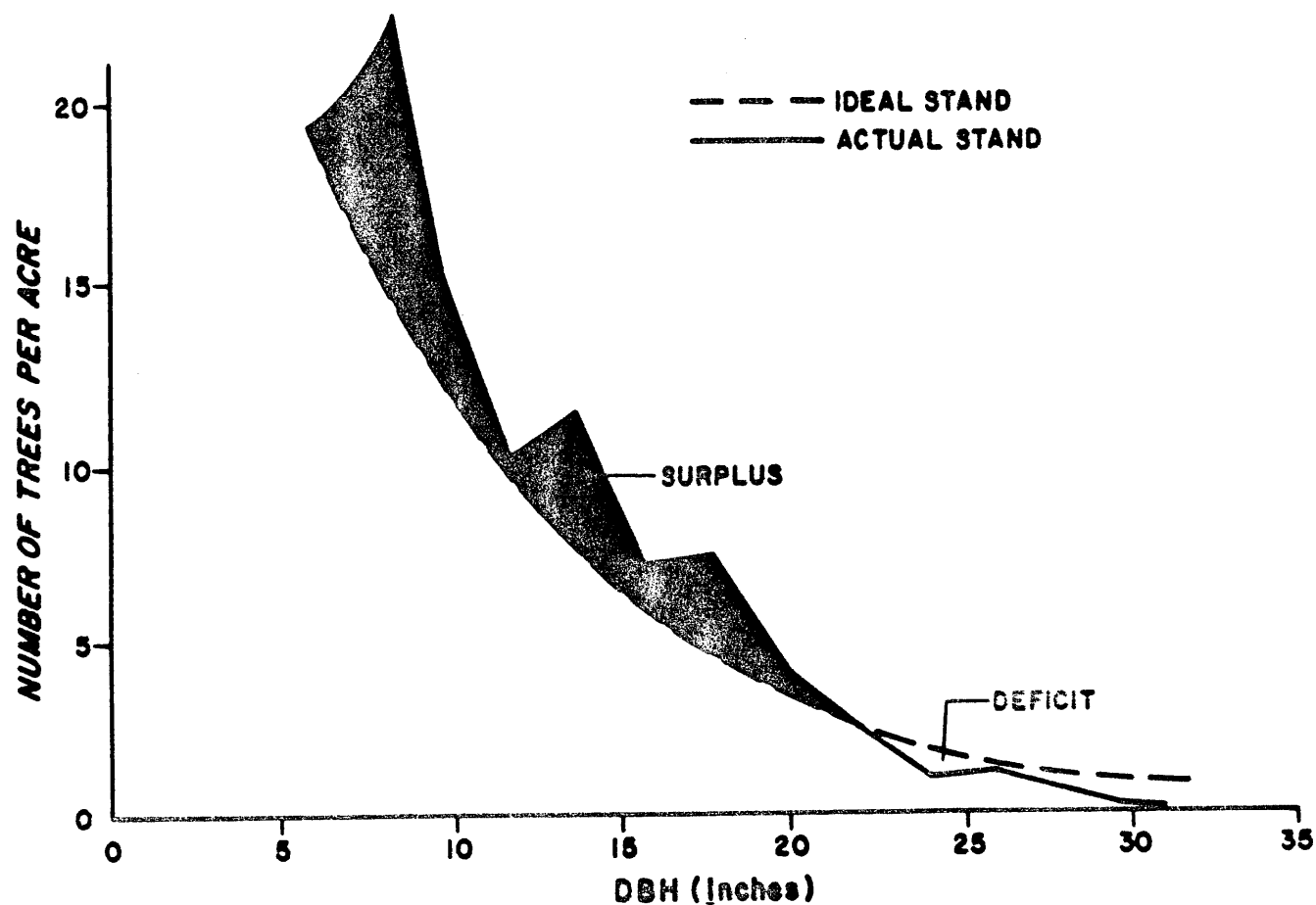
Uneven-aged management is used on 75% of our hardwood stands and has provided good results. It will not work if stands are high graded or picked at though. It requires some of the most sophisticated silvicultural prescriptions that we work with. In preparing these prescriptions first we decide which Q-factor we will be using for the stand in question. This Q-factor is basically the shape of our stocking curve for the stand (see Figure 4).

FIGURE 4



A Q of 1.1 would be used where more larger trees are desired for veneer or to create a big tree appearance in a recreation area. A Q of 1.7 will result in more small diameter trees and might be used for firewood management in an area near a town. Once a Q factor is decided upon we then compare the stands actual stocking against the desired stocking curve to determine what trees to cut (see Figure 5).

FIGURE 5



Finally, we develop instructions for the marking crew telling them what is out there, what to cut and what should be left (see Table 2).

TABLE 2
MARKING PRESCRIPTION - STAND 34
Q=1.5 ROTATION DIAMETER = 24"

Size Class	Current Stocking	Cut	Residual
0-4	7	0	7
6-10	55	25	30
12-16	40	10	30
18-24	35	10	25
25+	4	4	0
	141	49	92

The results will be regulated northern hardwood stands producing a high percentage of quality material on 10-20 year cutting cycles.

In conclusion, silvicultural practices in the Eastern Region come under close scrutiny. Through Forest Planning we have determined that we have adequate resources to satisfy reasonable demands for timber, recreation and wildlife.

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ALTERNATIVE SILVICULTURAL SYSTEMS - EAST

David A. Marquis
Project Leader and Principal Silviculturist
Northeastern Forest Experiment Station, Forest Service
U.S. Department of Agriculture,
Warren, PA¹

INTRODUCTION

Public pressures to provide more and more outputs of all types from our forest lands have increased dramatically in recent years. Silviculturists will have to significantly expand the range of treatments at their disposal to accommodate these demands, while maintaining the overall health and productivity of our forests.

In this paper I review some of the traditional silvicultural systems used in the Eastern United States, and suggest modifications and alternative cutting methods to meet a variety of forest management goals.

SILVICULTURAL ALTERNATIVES IN THE EAST

We have traditionally considered all silvicultural practices falling into one of two major categories: even-age and uneven-age systems. Regeneration cutting methods employed under even-age silviculture include clearcutting, shelterwood cutting, and seed-tree cutting. Those employed under uneven-age silviculture include single-tree selection and group selection. Within these two systems and five cutting methods there is wide variation in the manner in which the various cuttings are applied.

As we attempt to accommodate the more diverse demands being placed on forest management, we will find it increasingly difficult to use only these few traditional methods to categorize treatments. Many additional variations of cutting method will be needed. The clear distinctions between even- and uneven-aged systems will blur. We will need to shed the traditional limitations we have imposed on ourselves by the way we define silvicultural methods, and allow for much more flexible thinking on the specific combination of treatments necessary to meet today's needs.

This expanded range of silvicultural alternatives will strain our ability to communicate. If we greatly modify

the manner in which some traditional silvicultural practice is performed, but call it by its traditional name, we will confuse both ourselves and the general public. But if we give every cutting practice variation a new name, that too will confuse. So forest plans and other kinds of communications will need to define the silvicultural practices much more specifically than in the past. For example, we cannot assume that group-selection cuttings on the White Mountain National Forest in New Hampshire bear any resemblance to group-selection cuttings on the Wayne Hoosier National Forest in Indiana. In addition to saying that group-selection cutting will be applied, we need to specify the size of openings to be used, the methods used to regulate cutting, the types of cuttings to be used between openings, and similar factors that constitute the silvicultural system.

With these cautions in mind, I will list and define some of the silvicultural alternatives that are currently being used or studied in eastern hardwoods. Rather than discussing these under the traditional even-age and uneven-age categories, I will present them as a continuum of methods that incorporate a range of cutting intensities and regulation procedures. The sequence in which they are listed is intended to reflect their relative severity or favorability for such management goals as timber production, wildlife habitat, and aesthetics.

No Cutting

Although we rarely list it as a silvicultural technique, no cutting is clearly one of our most important management options. It is the only option that will meet wilderness objectives, and it has important application in many nonwilderness areas where aesthetics is a major goal of management. Under this option, I do not exclude all tree cutting. Trees may need to be cut to build trails, roads, recreational facilities, eliminate hazards, etc. But there is no systematic, planned series of cuttings designed to manipulate the vegetative cover.

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Single-Tree Selection

Under this system, single-tree selection cuttings constitute the sole cutting method. The intent is to create, within a single stand, a self-sustaining forest in which trees of several to many ages and sizes are present, intermingled with each other. Trees to be removed during each cut are selected on an individual basis. At every cut, tree regeneration is obtained, immature trees are thinned, and mature trees are harvested.

Cutting is regulated in single-tree selection via volume (or basal area) control by tree-size class. This means that a stand structure goal is established that specifies a residual density, maximum tree size, and diameter distribution (usually using the quotient "q" to define the diameter distribution). All trees in excess of this goal are cut periodically. While regulation of cutting within each stand is achieved via volume by size class, area control also is utilized to schedule cutting of stands within the overall forest area.

Where timber production is an important management goal, single-tree selection cuts in northern hardwood stands typically utilize residual relative densities of 55 to 60 percent, maximum tree sizes of 20 to 24 inches, and q factors of 1.3 to 1.5. Densities usually are allowed to build up to about 80 percent before another cut is made, providing a cutting cycle of 15 to 20 years.

Single-tree selection favors shade-tolerant species. In northern hardwood areas, sugar maple often is the object of single-tree selection management. American beech and eastern hemlock also are favored in areas where they occur. Fast-growing, high-value, shade-intolerant species such as black cherry, yellow-poplar, white ash, northern red oak, and white birch are gradually eliminated or reduced to minor components under single-tree selection.

In the oak type, where valuable shade-tolerant species are lacking, single-tree selection produces variable results. On some sites, less desirable but acceptable species such as hickory or red maple or slow-growing white, chestnut, or post oaks may eventually dominate the stand. On other sites, tolerant noncommercial species such as dogwood and sassafras may replace the commercially desirable oak species. On still other sites, northern hardwood species may take over, resulting in a type conversion.

As a result of its effect on species composition, single-tree selection usually produces less timber value than other methods (except no cutting). It is used primarily in northern hardwood regions where sugar maple is a desirable timber species.

However, single-tree selection has an important advantage in that it maintains a more natural, undisturbed appearance than other cutting methods. A high forest canopy is present at all times. When viewed from a distance, areas managed by single-tree selection often appear completely undisturbed, and they absorb much of the impact of disturbance even when viewed in the foreground. For these reasons, single-tree selection is especially appropriate in heavily used travel zones and areas of high recreation use on public forests. It also is widely accepted on small, privately owned woodlands where timber production is secondary to other goals.

Single-tree selection may have advantages for certain wildlife species that spend their entire life in mature forests for example, the barred owl, wood thrush, flying squirrel, and pileated woodpecker. Conversely, it adversely affects early successional species of wildlife such as deer, rabbits, snowshoe hares, ruffed grouse, bluebirds, and chestnut-sided warblers. Usually, there is less wildlife species diversity (the number of different species present) under single-tree selection than under other silvicultural methods.

Where single-tree selection is used primarily to meet visual or wildlife goals, the cutting specifications may need to be adjusted from those used for timber production. For example, some landowners may place a high value on the appearance of "primeval" forests that contain a high percentage of large trees. By raising the maximum tree size and reducing the q factor used to specify residual stand structure, it is possible to increase the numbers of large trees in a stand and thus dramatically change its visual impact over a period of time.

For certain late successional wildlife species, similar adjustments may be appropriate to increase the proportion of trees old and large enough to contain wildlife cavities. However, this objective can be achieved simply by reserving particular numbers of cavity and potential cavity trees rather than altering the structure of the entire stand.

Group Selection

At the Northeastern Forest Experiment Station, we have adopted a slightly more restrictive definition for group selection than is often applied elsewhere. We have done this because the range of cuttings sometimes labeled as group selection is extremely broad. By using the same term for all cuttings within this range, we tend to obscure important differences in environmental conditions and impacts on forest resources that are encompassed by these cuttings. This can lead to improper use of the method, and may be misleading to the public, which

has specific ideas on how this cutting method should be applied.

At the Northeastern Station we define group selection as a simple variation of single-tree selection. As with single-tree selection, a stand-structure goal is selected, cutting is regulated via volume control by size class, and individual trees are selected for cutting throughout the stand. In addition, groups of trees may be removed in locations where several adjacent trees need to be cut because of quality, size, vigor, or other factors. The openings created by these groups are small—usually a tenth to a quarter acre in size, and occasionally up to a half acre.

No attempt is made to keep track of the individual openings, nor to achieve any particular total area in openings. It is not expected that every part of the stand eventually will be included in an opening. Stands are marked and regulation is achieved in the same manner as with single-tree selection cuts, the only difference being that some small openings are created in the stand, with single-tree selection between the openings.

When openings are larger than a half-acre (at least in eastern hardwoods), the environmental conditions in the openings and the impacts on tree regeneration, wildlife habitat, and aesthetics become much more like those in clearcuts than those we associate with group selection. Further, it becomes impossible to regulate cutting via volume by size class. Therefore, we have chosen to restrict group selection to its original definition, and recognize methods that use larger openings and other regulatory procedures by a more appropriate term.

The addition of small group openings to the matrix of single-tree openings has several important advantages. It often allows the regeneration of less shade-tolerant species, thereby improving opportunities for both timber production and wildlife diversity. Small group-selection openings do not maximize percentages of shade intolerants, but they can increase representation of these species. Sometimes group selection will maintain acceptable tree species on sites that would be converted to noncommercial or low-value commercial species if single-tree selection were practiced exclusively.

So long as the openings are kept small, negative effects on aesthetics and loss of tree quality on trees bordering openings can be minimized. We generally recommend this combination of group and single-tree selection over single-tree selection alone for all situations in eastern hardwoods except those where some unusual visual or wildlife goal dictates single-tree selection only.

Two-age

Two-age silviculture is not widely recognized in eastern hardwoods but it is one that has many potential uses. The idea is to maintain two distinct age classes on the area at all times, with the two age classes exactly a half rotation apart.

Harvest-regeneration cuttings are essentially diameter-limit cuttings. But unlike the diameter-limit cuts that have given the method a bad name, these cuts result in the complete removal of one of the two age classes rather than high-grading the fastest growing individuals of a single age class.

Imagine a stand containing about half its stocking in trees 80 years old, and the other half in trees 40 years old. The harvest-regeneration cut would remove the older age class and thin among the younger age class, leaving a residual density of only 30 to 35 percent. The open conditions after cutting should allow the establishment of a new age class that is 40 years younger than the residual overstory. After a growth period of 40 years, the process can be repeated, perpetuating two age classes 40 years apart on the site at all times. Thinnings could occur in the years between harvest cuts if volumes warrant.

Such a system of two-age silviculture provides a compromise between traditional even-age and uneven-age methods. There is never a complete clearcut. Instead, a forest canopy is maintained on the area at all times, leaving a more acceptable appearance than clearcutting. In addition, the environmental conditions after each harvest cut allow the establishment of shade-intolerant species, and regulation of cutting can be accomplished by efficient area-control methods normally used with even-age management. Thus, higher timber values may be possible in locations where visual goals preclude traditional even-age methods.

Although the only areas currently under planned two-age management are experimental ones, there is ample practical evidence that this cutting method can produce the desired regeneration. Much of the so-called commercial clearcutting in the East at the turn of the century was diameter-limit cutting which left residual densities and structures like those described here. These cuts gave rise to many of our current stands that contain high-value species of several distinct age classes. So the method seems viable. The major unknowns are the magnitude of the tradeoffs to timber, wildlife, and visual resources relative to other silvicultural methods.

Even-Age with Aesthetic Shelterwood

This is another compromise method between the extremes of the more traditional even- and uneven-age procedures. In this variant, all of the traditional even-age techniques are used except for the final harvest-regeneration cut. Instead of clearcuttings or traditional shelterwoods to regenerate a new stand, the only harvest-regeneration method permitted is a shelterwood that utilizes a two-cut removal.

When the stand reaches maturity, a shelterwood sequence is initiated that may involve two or three cuts in total. The first, or seed cut, is intended to establish the required amount of advance reproduction. If previous thinnings already have accomplished this, the seed cut is omitted. But the removal cut always is made over two entries. The first reduces overstory density to 30 to 40 percent, providing enough light for the already established advance regeneration to grow to a height of 10 to 15 feet. Then, the remaining overstory is removed, usually 5 to 10 years later.

The purpose of the two-cut removal is to ameliorate the disturbed appearance of more traditional even-age harvest cuts. The large regeneration left after the final removal is sufficiently tall to cover stumps, slash, and soil disturbance, avoiding the period of unsightly appearance usually associated with even-age methods. This three-cut shelterwood sequence also is used for purposes other than aesthetics—to facilitate even-age silviculture on wet or rocky soils, for example, where large regeneration is needed to minimize site limitations.

As with any compromise, the impacts of this method must be weighed carefully for all resources. Often, it can produce timber regeneration equal to that from more traditional even-age methods, but at an increase in cost. It may have detrimental effects on early successional wildlife and on wildlife diversity, because the herbaceous early successional vegetation stage usually is reduced or eliminated. The importance of this effect depends on the specific wildlife management goal. Opinions on the visual improvement over clearcutting are highly variable, depending on the individual observer, the topography and view distance, and many other factors.

It is unlikely that any compromise method—such as aesthetic shelterwood or two-age silviculture—will find universal acceptance; nevertheless, but there is considerable opportunity to use them effectively in specific situations.

Patch Cutting

Patch cutting is one variation of what some might call group-selection cutting and others might call clearcut-

ting. But the application and impact of patch cutting is so different from either of these other methods as to make the distinction important.

Patch cutting entails creating small openings, usually between one-half acre and two acres in size. Not only are the openings larger than group-selection openings, but the method of regulation is different.

With openings of this size, it is virtually impossible to regulate cutting by establishing stand-structure goals and selecting trees for cutting based on their size. Instead, cutting is controlled by selecting the desired acreage to be included in openings. All trees in those openings are removed, regardless of their individual size relative to some stand-structure goal.

In effect, this method is mini-even-age management. Marking consists of identifying areas to be cut in openings rather than selective marking of individual trees and small groups of trees. The amount of acreage in openings at each cut is calculated as a function of the expected even-age rotation, and the cutting cycle. While the individual openings are not mapped and recorded separately, the total acreage included in openings at each cut is recorded; in fact, it is the method by which cutting is controlled.

With this method, there need be no partial cutting between openings; the harvest-regeneration cut can consist of clearcut patches only. If partial cutting is done between openings, either at the same time or a different time, it is done as a thinning rather than a selection cut. This method produces a series of even-aged groups of trees within a single uneven-aged stand. Each group is managed by even-age procedures even though recordkeeping is limited to the entire stand. The entire stand will assume uneven-age characteristics even though it is managed as a collection of small, even-aged groups. In all respects except size of area defined as a stand, this method uses even-age techniques.

In many cases, these patch cutting techniques have been adopted and labeled group-selection cutting in response to public reaction against clearcutting and even-age management. Unfortunately, the method has characteristics more like even-age silviculture than selection cutting as it is commonly being applied in eastern hardwoods, with openings that tend toward the 2-acre upper limit. Giving it a label that more accurately describes its application will help to ensure that the public is not misled by our forest plans. This also will clarify its position in the continuum of silvicultural treatments, and aid in the accurate assessment of resource impacts and achievement of desired future forest conditions.

Even-Age

This is no-holds-barred, traditional even-age silviculture. It includes any even-age harvest-regeneration cutting method that may be needed to achieve desired results, including clearcutting, shelterwood cutting in any of its many variations, and seed-tree cutting. Even-age silviculture includes thinnings and similar intermediate cuttings in immature stands. And it may include a host of other cultural practices, such as site preparation and artificial regeneration, when they are needed.

In eastern hardwoods, most of the desired species, including the oaks, black cherry, white ash, red and sugar maple, and beech depend on the presence of advance seedlings to regenerate successfully after final overstory removal. Thus, clearcutting is really a one-cut shelterwood where nature or past thinnings have made the seed cut unnecessary. Two-cut shelterwoods commonly are used to improve advance regeneration where it is inadequate either in numbers or size.

Many hardwood seeds exhibit delayed germination so that often there is a considerable seed supply buried in the forest floor. Yellow-poplar, white ash, and black cherry are notable examples. As a result of these factors, and the fact that tree seedlings and herbaceous plants make seedbeds unreceptive to new seeds within a few years of final harvest cutting, seed-tree cutting is rare in eastern hardwoods. Likewise, artificial regeneration is seldom employed; natural regeneration established well before the final removal cut is the rule.

In the eastern hardwood region, clearcutting, shelterwood cutting, and seed-tree cutting generally are considered cutting methods under a single silvicultural system (even-age silviculture); they are not separate silvicultural systems in themselves. The cutting method is selected on the basis of advance regeneration, interfering plants, and site conditions in each individual stand, but the end results are even-aged stands that are managed similarly thereafter.

Even-age silviculture generally results in forests with a maximum proportion of fast-growing, shade-intolerant, high-value species such as black cherry, white ash, red oak, yellow and white birch, and yellow-poplar. As a result, even-age silviculture generally yields greater returns from timber management than any other system.

Because it is the only system that includes large openings likely to go through an herbaceous plant stage, while also including stands of trees of many age classes (including some mature ones), even-age silviculture generally provides greater wildlife species diversity than any other system. It also can favor an abundance of wildlife species

associated with early successional vegetation. Examples include deer, rabbits, snowshoe hares, ruffed grouse, bluebirds, and chestnut-sided warblers.

In the East, clearcutting used in even-age silviculture is the only effective method for increasing water yields from forested watersheds. However, its use for this purpose usually is restricted to municipal watersheds.

Visual effects of even-age silviculture differ widely. Many people find the appearance of fresh clearcuts objectionable, and there has been considerable public pressure to avoid clearcuts and other forms of even-age silviculture for this reason.

On the other hand, even-age silviculture has been used by landscape architects to create variety in the landscape that some find more pleasing than unbroken blocks of forest cover. Even-age methods can encourage the establishment of flowering plants and other attractive vegetation. And public objections to clearcutting often can be minimized by careful application of even-age silviculture—limitations on opening size, blending of shape to fit existing vegetation patterns, measures to reduce slash and soil disturbance, etc.

Nevertheless, clearcutting and associated even-age management practices clearly are unacceptable to the general public in many circumstances despite their biologic and economic advantages. They are the least suitable procedures for use on areas where recreation use is high or where a natural, undisturbed appearance is essential.

The even-age system is easily adapted to meet a variety of objectives. In addition to some of the modifications to ameliorate visual impacts described here, there are many other useful variations.

Rotation length can be varied to suit a wide range of objectives. Rotation lengths usually are set to maximize financial returns from timber. But shorter rotations may significantly increase the abundance of wildlife that depends on early successional vegetation. For example, rotations as short as 40 years have been recommended for grouse, rabbits, and deer. Longer rotations may have even greater utility. Longer rotations increase the proportion of area occupied by large trees, and increase the numbers of cavity trees and the amount of mast available.

Retaining selected individual trees that normally would be cut is another important way to improve timber yields, wildlife habitat, and aesthetics. Retaining selected residuals at the time of final harvest can lessen the visual impact of the cutting, retain rare, slow-growing, or difficult-to-regenerate species in the next stand, in-

crease vegetation diversity (both species and vertical diversity), and maintain mast production and perch and cavity-tree density. This technique also may make earlier commercial thinnings possible in some circumstances. It is extremely important that the trees retained for this purpose be selected carefully. The procedure will produce the desired result only if the proper number of trees of the appropriate species and form are retained; retaining unneeded trees or too many or the wrong kinds of trees can be detrimental. Nevertheless, the idea that clearcuts must include the removal of all stems often is inappropriate for multiple-use management in eastern hardwoods.

Retaining selected trees for wildlife or other purposes is not restricted to final harvest cuts. Existing and potential cavity trees need to be considered for retention at every cutting entry in a stand to ensure maximum benefit.

The modifications discussed here are appropriate in nearly all silvicultural systems, not just even-age procedures. Rotation lengths can be extended in any of the methods that employ area control, and selected trees can be retained in any cutting method.

IMPACT OF SILVICULTURAL SYSTEM ON FOREST RESOURCES

The silvicultural systems described do not represent all possibilities, but they illustrate the range of methods available. In selecting an appropriate system to meet a particular set of management objectives, it is essential that consideration not be limited to traditional methods applied in traditional ways. We need to avoid methods that are biologically infeasible, but we also need to stretch our thinking to include variations on proven methods that may meet our needs better than more traditional techniques.

A key in all of this, of course, is to make an accurate evaluation of the potential impact on all resources of any proposed silvicultural system. I have evaluated the impact of the silvicultural systems described for several of the major resource values, using conditions common in the Northeastern United States.

In interpreting the charts that follow, bear in mind that results may vary widely among forest types and geographic areas. In some cases, an existing forest type cannot be perpetuated by some of the silvicultural methods listed. For example, Central States oak-hickory probably cannot be perpetuated by single-tree selection, but it can be maintained by most of the other procedures described. Aspen-paper birch can be maintained suc-

cessfully only by methods at the even-age extreme. Still others, such as northern hardwoods, often can be managed by any of the systems listed.

For most types, there is an opportunity to accommodate a range of management objectives by selecting silvicultural systems that offer an appropriate compromise among the various resources. Equally important is the ability to modify the way in which each system is applied to achieve the desired combination of effects, for example, altering rotation lengths, residual stand densities and structures, retaining selected individual trees during cuttings that normally would remove them, and similar practices.

Timber Value

In general, value realized from timber production is a function of the species of trees favored by the various silvicultural systems. Selection-cutting systems that favor shade-tolerant, slower-growing, and often less valuable species usually yield the lowest values. Even-age systems that favor fast-growing, high-value, shade-intolerant species generally yield the highest timber values (Figure 1). Exceptions include forest types where the most valuable species are shade tolerant, such as Lake States northern hardwoods (sugar maple), where differences in timber yield among silvicultural systems are minor.

Natural Forest Appearance with Continuous Canopy Cover

By contrast, the ability of the various systems to maintain a natural forest appearance, including a continuous high forest canopy, is the direct opposite of that for timber yields (Figure 2). Figure 2 also might be considered a representation of the degree of public acceptance of various silvicultural methods. Although it is extremely difficult to determine the exact basis of this acceptance, it does appear to follow the general pattern illustrated here.

However, this chart should not be considered as representing the effect of these silvicultural systems on other aspects of aesthetics or landscape management. For other specific visual objectives, such as visual diversity or abundance of particular attractive plant species, the relative favorability of the various methods may be quite different.

Abundance of Particular Wildlife Species

To evaluate the impact of silvicultural methods on wildlife species, it is important to consider each wildlife species individually. The effect of particular methods

may vary significantly among wildlife species that are classified as depending on the same stages of forest vegetation. Therefore, the patterns illustrated in Figure 3 for early and late successional wildlife species should be interpreted as generalities that may not apply to any individual species.

The primary point here is that different wildlife species have markedly different requirements, and methods that favor one group invariably will discriminate against others.

Wildlife Species Diversity

In addition to evaluating the impact of silvicultural methods on individual wildlife species, it is important to consider impacts on wildlife communities as a whole. One measure is wildlife species richness or diversity. While no silvicultural system will benefit all wildlife species, those methods at the even-age end of the range tend to provide for at least minimal populations of a wide variety of species (Figure 4). Wildlife species diversity appears to reach a maximum at this end of the silvicultural system continuum.

For both Figure 3 and 4, it must be remembered that many wildlife habitat factors are affected more by the manner in which cutting is done and the attention paid to special wildlife requirements than by the particular silvicultural system used. The availability of snags and den trees, of perches, of dead and down logs, of suitable cover in strategic locations, and similar factors can be achieved by modifying the cutting rules for most of the silvicultural systems listed.

SOME CONCERNS

The figures illustrate general patterns for only a few of the specific resource values that need to be evaluated. Unfortunately, we do not have as much information as we would like on the impacts of many of these silvicultural methods, especially on resources other than timber. And we probably will never have all of the information we need. So we must learn to extrapolate from what we know about traditional methods to some of the untested alternatives.

Much of that was done in the last round of forest plans. It was a good effort, but I have some concerns that in our zeal to satisfy the demands of our public, we may have created several problems for ourselves in the future.

In making assessments of the impact of relatively untested silvicultural practices, we must think in terms of a forest containing all stages of development appropriate to the

system in question. And we must avoid ascribing benefits or disadvantages that do not exist, or that can be altered significantly by modifications in the application of the method.

To illustrate, the following admonitions are made in response to common errors in assessments that I have seen in eastern forests.

- o We must not associate single-tree selection with larger quantities of oak mast than even-age silviculture on the basis of maintaining more area in mast-producing sizes of trees if, in fact, single-tree selection eventually will result in conversion to species other than oak.
- o We must not associate the abundance of large trees suitable for wildlife dens with a particular cutting method when, in fact, it is more a function of the manner in which that cutting is applied. Selection of maximum tree size and q factor in selection cutting, selection of rotation length in even-age silviculture, and retention of actual and potential den trees during all cuttings are far more important than the cutting method itself.
- o We must not apply the extremes of any cutting method and assume this will have the same impact on resource levels as more traditional variations of the same method. Patch clearcuttings of 2 acres applied in an even-age context cannot be assumed to satisfy public objections to clearcutting anywhere near the same degree as true group selection, no matter what name we attach to it.
- o We must recognize that good timber management is not necessarily good wildlife management, as we have often assumed in the past. The requirements of all early succession wildlife species will not be satisfied simply by adopting even-age silviculture. Nor will we help all late-succession wildlife by using selection cutting or long even-age rotations. The requirements of these species often are tied to specific habitat features associated with natural old-growth forests, or with natural forest openings—features not provided by simply adopting the silvicultural method that seems to most closely duplicate the natural forest structure. Large quantities of dead and down trees required by certain late-succession wildlife, for example, are no more likely to be present in an intensively managed selection forest than they are in an even-aged forest.

SUMMARY

Rather than a few cutting methods grouped into two discrete silvicultural systems, there is a nearly limitless

continuum of silvicultural practices available. By selecting from an array of systems, by modifying the cutting practices and regulatory procedures within each system, and by supplementing the traditional timber management practices with measures designed specifically for other resources, it is possible to meet the diverse needs of a wide range of forest management objectives.

Creative extension of traditional methods and careful analysis of the impacts of this wide range of options are critical. Although there are many gaps in our knowledge, and much additional research is needed, we must do the

best job possible with the information we now have.

In the Northeast we are attempting to synthesize the best existing information on forest management for timber, wildlife, and aesthetics into a multi-resource decision model. This computer-based expert system will provide both individual stand and management unit recommendations on integrated forest management. We hope that this new model will help forest land managers select the optimum silvicultural practices to meet a wide range of multi-resource management goals.

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ALTERNATIVE SILVICULTURAL SYSTEMS
ON SOUTHERN NATIONAL FORESTS
A STATUS REPORT

Robert N. Kitchens
Regional Silviculturist
Southern Region
U.S. Forest Service

Abstract

Due to increased opposition to clearcutting, Southern National Forest plans have prescribed increased use of other harvest cutting methods. These cutting methods along with their attendant complete cycle of treatments can collectively be called Alternative Silvicultural Systems. Most were planned to be applied in highly visible areas, and are designed to be more visually acceptable than clearcutting. Some of these cutting methods with variations go beyond research results. As such there are many, many questions. With several years of experience, some answers are beginning to be known.

INTRODUCTION

During Forest Plan development, opposition to clearcutting became an issue on many of the National Forests in the South. In response to that issue, additional amounts of other harvest cutting methods were planned. This includes increased plans to use shelterwood and seed tree cutting in even-aged systems, and on some forests, considerable acreage was allocated to uneven-aged management. Most of the increased use of alternatives to clearcutting were for visual reasons; however, some is being done to increase the oak component in regenerated stands. Most alternative harvesting methods are planned in management areas with a high degree of visual sen-

sitivity (along heavily travelled roads and around lakes, recreation areas, etc.). The management prescriptions for these alternative methods are quite varied and each have some biological, economic, and even scenic questions which must be answered. As more and more of the prescriptions are implemented each year, answers to these questions will develop. However, many of the most serious biological questions will take decades to answer. Some examples are: (1) Can regeneration of desired species be obtained and developed? (2) Will volume production be sufficient over the long-haul? (3) Can we afford the increased costs in face of the below-cost issue? (4) How dysgenic are these practices?

LAND ALLOCATION

The National Forests in the South have a total of about 12 million acres. Roughly 8.7 million of that is classified as suitable for timber production. Current plans and draft plans plus court-ordered management on the National Forests in Texas shows 8.1 million acres or 93% allocated to even-aged management systems. Seven percent or 646 thousand acres is allocated to uneven-aged systems. Thus, the bulk of the acreage managed for timber is still to be by even-aged management. However, the shift toward uneven-aged management is a significant one and has many implications.

Table 1. Summary of Southern National Forest Planned Annual Acres by Cutting Method

Cutting Method	Average Annual Acres	Percentage
Clearcut	76,531	32
Prep Cut	4,518	2
Seed Cut	15,635	6
Removal	7,770	3
Selection	37,474	16
Thin	95,255	40
Salvage	2,200	1
TOTALS	239,383	

Percentage of Suitable Land = 2.7%

Total Even-aged Regeneration Harvest = 96,684 Ac/Yr

% of Suitable Land = 1.1%

EVEN-AGED SYSTEMS

As you can see from Table 1, even-aged management with clearcutting will still be the predominant method of regeneration. There are many reasons why this is so. For pine regeneration, planting success is routinely achieved on 90 + % of the sites the first time. Stocking control is maintained, and over 92% of the sites are stocked with first-generation improved seedlings which grow faster and produce better quality wood than general forest area stock or natural regeneration. Another major reason to plant is to regenerate longleaf pine back on sites it previously occupied but was replaced with other species.

Hardwood stands regenerate well from clearcutting with desired species except on moist sites where one of the most desired species, Northern red oak, is usually lacking. Some planting is now being done in clearcuts with first-generation improved black cherry and some of the bottomland oaks. An exciting new development in hardwood regeneration is the use of shelterwood cutting to increase the Northern red oak component in stands. This is one of the reasons for a shift toward shelterwood cutting on moist cove sites.

Pine Alternatives

Seed tree

The seed tree method has been used successfully for many years in loblolly, slash, and shortleaf pine so this alternative is not new; only the acreage will be increased under the new Forest Plans. Since shortleaf pine is sometimes a sporadic seeder, we are actually planting under seed trees in some stands. This assures regeneration and gives us the benefits of superior stock while satisfying visual concerns. As with all seed tree cuts, wrong timing will give an overabundance of reproduction and will require a pre-commercial thinning treatment.

Shelterwood

Since longleaf pine only rarely produces a heavy seed crop, a two-cut or three-cut shelterwood is the preferred method of even-aged natural regeneration. The three-cut method is needed if overstory exceeds 70 to 80 square feet of basal area. The preparatory cut is made 3 to 10 years ahead of the seed cut. The purpose to the preparatory cut is to develop larger crowns and thus increase seed production. Preparatory cuts should leave from 60 to 70 square feet of

basal area. The seed cut is then made leaving 25 to 30 square feet basal area of the best trees as parents of the new stand. Of course, as with all natural systems, timing is extremely important to achieve the desired results. Some shelterwood cuts in longleaf reproduce a new stand in 5 to 7 years whereas other stands may still be in regeneration 14 years or more after the seed cut and still not be stocked (Boyer 1986). Aesthetically, longleaf shelterwood cuts are quite pleasing due to the beauty of the species and the park-like nature of the cut stands. A possible conflict between the biological requirements of the species and aesthetic management is the need to remove the overwood before many seedlings begin height growth (ideally the second growing season). Otherwise the overwood seriously interferes with the growth and development of the new stand (Boyer 1963).

Other pine species may be regenerated by the shelterwood method but the primary reason for using this method is aesthetic since the silvical characteristics of the other pine species do not require the shelterwood method.

Hardwood Alternatives

Research results show that the species composition for naturally regenerated Southern hardwood stands is essentially the same whether the stand is clearcut, seed tree, or shelterwood (except pretreatment of shelterwood 10+ years prior to shelterwood cut). Therefore, if a stand is to be regenerated by commercial sale, the only reason not to clearcut is for aesthetics. We are prescribing and making shelterwood cuts leaving 20 to 30 square feet of basal area. Sometimes the leave trees are of high quality and sometimes they are not—the decision on what trees to leave is based on aesthetics and apparently it doesn't matter to the public whether they are the highest quality timber trees or the poorest. The important point is that a forested appearance always is present. If poor quality trees are left, then they can't be removed in a commercial sale and we are faced with either paying for removing them or leaving them to the detriment of the new stand.

A possible variant of this method is to always grow a two-aged stand. The leave trees can be left to the next reproductive cycle, if they will live that long. Some of our species can be managed that

way (Northern red oak, white oak) and some cannot (scarlet oak).

One of the most exciting developments in Appalachian Hardwoods is a silvicultural regime to develop Northern red oak regeneration on moist sites. Developed by Don Beck and David Loftis, the system involved treating the mid-story with herbicides and letting Northern red oak seedlings develop to the point that when the overstory is removed, they can compete with yellow-poplar and other fast growing species (Loftis 1988). A variation of this system, which we are working on involves reinforcement planting of Northern red oak in British tree shelters in the stands coincident with the mid-story treatment. This will allow us to use genetically improved stock and will be a huge step forward in maintaining genetic diversity on those sites. Region 8 has a 16-year old, 120-family, Northern red oak orchard in Tennessee which is on the verge of commercial production so the timing for this work is perfect. The major drawback to this system is that no commercial sale can be made in the first treatment so we must get 10 years ahead of the regeneration cut with our prescriptions and treatments.

UNEVEN-AGED SYSTEMS

Nine forests in the Region have uneven-aged management in the Plans. Table 2 shows an estimate of what could be in the final plans (several plans are not final). Both single-tree and group selection methods are being used on Southern Region National Forests. Note how different the acres to treat annually is depending on whether group or single-tree selection is to be used. The largest allocation for uneven-aged management is on the National Forests in Texas. This is a court-ordered plan designed to improve the habitat for the red-cockaded woodpecker. The Court called the management uneven-aged; however, there are several features the Court ordered which make it biologically difficult, if not impossible, to sustain an uneven-aged system. Namely, frequent prescribed burning and leaving 40 square feet BA of the largest trees in perpetuity. We have appealed the order but the appeal is yet to be decided. Most hardwood acres allocated to uneven-aged management are being regenerated with group selection.

Table 2. Summary of What Could Be* in Uneven-aged Management in R8's Forest Plans

Forest	Harvest Cutting Method	AC Allocated To UNEA	AC to Treat Annually
Chattahoochee	group	5,000	50
Cherokee	group/single	37,220	325
Florida	group	5,000	60
Geo. Wash.	group	60,000	400
Ouachita	single/group	150,000	15,000
Ozark	group	110,000	1,000
Nantahala-			
Pisgah	group	54,500	339
Jefferson	group	24,000	300
Texas**	single/group	200,000	20,000
TOTALS =		645,720	37,474
Percent of Suitable Land =		7.4%	

*Some plans still are not final.

**Court ordered management that does not meet the criteria of UNEAM, i.e. lacks ability to develop regeneration, other size classes, and sustained yield.

Hardwoods

Group cuts from one-half to two acres are being made in hardwood stands chosen for uneven-aged management. Most of these cuts have been done by dividing total stand acreage by the cutting cycle and prescribing the approximate area to harvest in small group openings. Thus far, almost all of the sales prepared have sold and the buyers appear to be pleased with the sales. We did find out that the area with group selection cuts must be near an already constructed road or have very little road building required. Due to the spread-out nature of the volume harvested, these sales won't support much additional road building. Thus far, public acceptance of the harvest has been on the positive side although we've not harvested many total acres in any one locality. Thus it is much too early to claim this type of regeneration cutting practice will satisfy all the opposition to clearcutting. In fact, except for size, the areas look precisely like clearcuts. After several entries, these stands will look quite different and unlike any present stands. It remains to be seen if they will be considered "natural looking."

Pine

The Ouachita National Forest (Arkansas and Oklahoma) Draft Land Management Plan has 150,000 acres allocated to uneven-aged management in the Preferred Alternative. The forest type is predominately shortleaf pine. The Draft Plan allows for group or single-tree selection. Current thinking is to use single-tree selection patterned after the model at the Crossett Experimental Forest. Regulation will be by the BDQ method (basal area, maximum diameter, and quotient-ratio of number of trees in successive diameter classes) (Farrar and Murphy 1989). Cutting cycles are planned to be between 7 and 10 years. The better the site quality, the shorter the cutting cycle. Thus far, several hundred acres have been cut, leaving 60-70 BA. Since these first cuts are in well-stocked, even-aged stands, they look no different than an even-aged thinning. On subsequent entries, these stands will take on a far different appearance. The key to making the uneven-age system work in shortleaf pine will be whether or not regeneration can be developed and grown through subsequent diameter classes.

Hardwood control has been shown by research to be a necessary ingredient in this system. Since a hardwood component is desirable from a wildlife, diversity, and esthetic standpoint, it remains to be seen just how much hardwood can be left in these stands and still develop the size classes needed for uneven-aged management. The recommendations for the Crossett Experimental Forest in loblolly-shortleaf pine stands is for almost complete hardwood control every cutting cycle.

The National Forests in Florida plan to use group selection in longleaf pine on about 5000 acres. There is no long-term research to know how well this might work. The Escambia Experimental Forest in southern Alabama started in 1977 a group selection system in a 60-year old stand on a site index 70 (50 year basis). Thus far, development of reproduction appears adequate to sustain the stand but board foot growth has only been enough to harvest 1,694 feet in 10 years (169 bf/acre/yr).

The George Washington National Forest in Virginia has established group selection harvests in white pine. The groups are up to 2 acres in size and thus far they have been well received by the public. The cuts are only two years old and it is too early to tell about the regeneration.

RESULTS

Although we've only been doing some of these alternative methods for a few years, some results are evident. On the positive side, apparently the public likes these methods better than clearcuts. Thus far, it doesn't seem to matter that it might take many more years for adequate reproduction, growth loss may be significant, or even that species composition may change to less desirable ones. As long as they don't have to view a clearcut, they will accept all the costs.

At least this is the short term view. When some of the longer term changes are evident, a different reaction may develop.

Selection cuts will sell if packaged attractively and near roads. Many of our selection areas were sold in the same sale with even-aged cuts so the total sale package was economical. In a few instances, selection cuts were sold separately and in most cases,

the buyers were pleased. The uneven-age methods all cost more to produce a unit of timber. This will make some of our below-cost forests further in the hole. Interestingly, some of the same groups who advocated the changes in timber management methods to more expensive ones are some of the same groups who keep berating us about below costs.

The question of how single-tree selection will affect the gene pool is an interesting one that will take many years to understand. Since we use size as a surrogate for age, the fastest growing trees tend to be selected for harvest sooner than slower growing ones. Thus the slower growing trees are in the stand longer to spread their progeny. This could be dysgenic.

CLOSING

These are exciting times for silviculturists. We are called upon to use all our ingenuity to manage the forests in ways different from the past. We are venturing past the limits of research. There will be successes and failures. There are many long-term questions unanswered.

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ALTERNATIVE SILVICULTURAL SYSTEMS—SOUTH

James B. Baker
Southern Forest Experiment Station
USDA Forest Service
Monticello, AR¹

ABSTRACT

Most of the commercially important pines occurring in the southern United States can be regenerated with a variety of reproduction cutting methods and managed under either even-aged or uneven-aged silvicultural systems. Because many southern pines conform to various management systems, silviculturists and resource managers in the South have an opportunity to manage and use a valuable renewable natural resource while preserving, protecting, and providing many of the non-timber values demanded by the public.

INTRODUCTION

For the past three decades, plantation culture has been the dominant regeneration method and management system used on most National Forests and forest industry lands in the South. In fact, plantation management—an even-aged system that utilizes clearcutting and artificial regeneration as a means of stand establishment—is considered by many to be the “norm” or standard for managing southern pines. Southern pines, however, are also regenerated naturally from seeds provided by trees growing on or adjacent to the site. Thus, resource managers have the opportunity to create either even-aged or uneven-aged stands by using different reproduction cutting methods that take advantage of natural regeneration. This paper will concentrate on alternatives to plantation culture. Upland or bottomland hardwoods, although important in the South will not be included in this discussion.

METHODS OF REPRODUCTION USING NATURAL REGENERATION

Managing for natural regeneration uses harvesting methods and cultural treatments to establish and develop a new stand from seed produced on or adjacent to the area. If an adequate seed source is available, managing for natural regeneration is a practical alternative on many sites to planting. One disadvantage of managing for natural regeneration is that there is little opportunity to use or benefit from genetically improved planting stock.

The silvical characteristics of loblolly and shortleaf pine make these species suitable for regenerating and managing as either even-aged or uneven-aged stands on most sites within their natural range. Longleaf and slash pine, however, are better adapted to even-aged methods. The following chart summarizes the natural reproduction methods that can be used for the four important southern pines:

Methods of Reproduction	Adaptable Species
1. Even-aged silviculture	
a. Clearcutting	Loblolly, shortleaf, slash pine
b. Seed-tree	Loblolly, shortleaf, slash pine
c. Shelterwood	Loblolly, shortleaf, slash, longleaf pine
2. Uneven-aged silviculture	
a. Single-tree selection	Loblolly, shortleaf pine
b. Group selection	Loblolly, shortleaf, longleaf pine

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When natural reproduction cutting methods are used for slash pine, precommercial thinning is often required since this species tends to stagnate in dense, young stands. When group selection cutting is used for longleaf pine, the group cuts should be at least one-half acre in size.

Successful natural regeneration depends on suitable site, stand, and climatic conditions allowing for the germination, establishment, and development of pine reproduction. For example, natural regeneration will fail if seedbed preparation is inadequate, if seed production is too limited, or if competing vegetation and/or climatic factors prevent survival or development of established seedlings.

Even-aged Methods of Reproduction

If even-aged stands are desired, the following methods of reproduction can be employed to secure natural regeneration.

Clearcutting. For loblolly, shortleaf, and slash pine, clearcutting can be used to regenerate small blocks, patches, or narrow strips if there is an available seed source from adjacent stands. The long axis of the clearcut areas should be perpendicular to the direction of prevailing winds. To ensure adequate seeding over the entire area, the clearcut should not exceed 300 feet in width. This method is generally not suitable for longleaf pine because seed dispersal is limited to short distances.

Most southern pine species can be regenerated by clearcutting with either seed- or seedlings-in-place. Seed-in-place involves clearcutting the stand after cone maturity or seedfall but prior to seed germination (September through March).

Probably the most common, and perhaps the best, application of seed-in-place is to clearcut the stand after the cones have reached maturity, but before they open. The mature cones that are distributed in the logging slash will then open and seed will fall on a scarified site. If logging is done after seedfall, many seeds are buried in logging debris.

With seedlings-in-place, clearcutting is done in late summer following a good seed year. Ample seed crops are necessary for successful use of these methods. Also, it should be noted that both methods involve a high risk, since they provide a one-time chance for successful natural regeneration.

Some of the advantages of clearcutting are:

- Management areas are easily defined and treated.
- Harvesting and cultural operations are concentrated in time and space.
- No high-value trees are left on the area.
- A relatively low level of technical skill and supervision is required.
- Wildlife that is dependent on early successional vegetation benefit.

Some of the disadvantages of clearcutting are:

- A large amount of logging debris may be generated.
- Fairly intensive site preparation is sometimes required.
- Seedling density is uncontrolled.
- The regenerated stand is susceptible to hazards.
- No merchantable material can be harvested from new stand for a relatively long period of time (15 to 20 years).
- The visual qualities of the forest are abruptly and drastically altered which is viewed by some as undesirable.
- Wildlife that is dependent on mature trees may be displaced.

Seed-tree. The seed-tree method can be used for loblolly, shortleaf, and slash pine and requires cutting all but 4 to 20 well-spaced, high quality seed-bearing trees (6 to 11 square feet of basal area) per acre. The number of seed trees retained depends on species, tree size, and site conditions. The minimum recommended number

of seed trees for various species and sizes are given in table 1. The seed-tree method is not recommended for longleaf pine because seed production and dispersal are not adequate with as few as 20 trees per acre.

Table 1. Minimum recommended number of seed trees and basal area square feet) per acre by species and size for pines growing on average sites (adapted from Williston and others 1982)

DBH	Loblolly		Shortleaf		Slash	
	No.	BA	No.	BA	No.	BA
	per acre					
10	12	6	20	11	12	6
12	8	6	14	11	8	6
14	6	6	10	11	6	6
16+	4	6	8	11	4	6

Before the reproduction cut, the area is normally prescribed burned to prepare a seedbed and control small hardwoods. The reproduction cut should be timed so that an adequate seed crop will be dispersed on a site freshly scarified by logging or seedbed preparation techniques. To ensure obtaining adequate seed, seed trees can be released three to five growing seasons before the reproduction cut. The release of the seed trees will enhance seed production during the first year after the reproduction cut. This technique is particularly important if the crowns of the seed trees are small. The seed trees are usually removed 3 to 5 years after adequate reproduction (at least 1,000 to 1,500 well-distributed seedlings per acre) has become well established.

Advantages and disadvantages of the seed-tree method are similar to clearcutting with the following additions.

Advantages:

- There is no need to rely on adjacent stands for seed, thus larger areas can be established and treated efficiently.
- Delayed removal of seed trees following stand regeneration is a safeguard against loss from fire or climatic agents.
- Some precommercial thinning can be accomplished, if needed, by skidding logs from the removal cut through dense patches of reproduction.
- The species composition can be controlled.
- Some trees are retained on the site during the regeneration phase which softens the visual impact.

Disadvantages:

- Seed trees may limit site preparation and slash disposal operations.
- The seed source is exposed to lightning, wind, and other hazards.
- The removal cut of seed trees may not be economically practical.

Shelterwood. The shelterwood method is similar to the seed-tree method, except more trees are left to regenerate the area. The seed-producing trees should comprise 20 to 30 square feet of basal area per acre (table 2). Like the seed-tree method, the number of trees left depends on tree size, species, and site and stand conditions. However, leaving more trees will usually help suppress the development of competing vegetation and provide more seeds for stand establishment.

Table 2. Number of trees required to leave shelterwood basal area of between 20 and 30 square feet per acre

DBH	Lower limit, trees per acre	Upper limit, trees per acre
10	37	55
12	25	38
14	19	28
16	14	21
18	11	17

The shelterwood method is suitable for most southern pines and is the recommended natural regeneration method for longleaf. The shelterwood method may be preferred over the seed-tree method in areas where seed production is sparse or erratic e.g., loblolly in the western extremities of its range and shortleaf in the Interior Highlands.

A two-cut shelterwood (one reproduction cut plus one removal cut) is usually recommended unless the parent stand is overstocked. In unthinned or dense stands, a release or preparatory cut may also be required to promote thrifty seedbearers. Hardwood control should be initiated before the reproduction cut. Prescribed fire can often adequately control small hardwoods, however, herbicides are usually required for larger stems.

Once adequate pine seedlings become well established following the reproduction cut (usually within 3 to 6 years) the seed trees are removed. If seedlings are too dense—over 5,000 stems per acre—some precommercial thinning can be accomplished by skidding logs through dense patches of reproduction.

Some of the advantages of the shelterwood method are:

- Slash disposal is less necessary than with clearcutting or seed-tree methods.
- The shelterwood overstory often suppresses development of competing vegetation.
- Residual shelterwood trees continue to produce high-quality growth until they are removed.
- The species composition can be controlled.
- The method provides better site protection and is more pleasing aesthetically than the clearcutting and seed-tree method.

Some of the disadvantages of the shelterwood method include:

- Large numbers of residual trees are subject to logging damage and impede harvesting and site preparation.
- The shelterwood overstory may hinder growth of pine seedlings.
- The method may produce excessive seedlings, requiring precommercial thinning.
- The method requires adherence to scheduled treatments and harvests.

Uneven-aged Methods of Reproduction

If the management objective is to maintain an uneven-aged stand—where seedlings, saplings, pulpwood, and small and large sawtimber are all represented—and to harvest at relatively frequent intervals, the selection method is the best alternative for some southern pines. Uneven-aged management is particularly suitable

for loblolly and shortleaf pines and can be used to some extent in longleaf. The system is not suitable for slash pine, because this species tends to stagnate in dense, young stands.

Single-tree and group selection involves periodic cutting, at 3 to 10 year intervals, of selected trees from all merchantable diameter classes. In fully stocked stands (60 to 75 square feet of merchantable basal area per acre, with two-thirds to three-fourths of the basal area in the sawlog component), harvested volumes generally approximate growth for the cutting cycle. In stands that are not fully stocked, only a portion of growth is cut.

With single-tree selection, trees selected for harvest can be single isolated trees or small groups of trees. Group selection involves cutting larger groups of trees on areas up to 2 acres so that discernible openings are created. If at all possible, the worst trees should be cut and the best trees left so that stand quality and growth will be improved.

To maintain an adequate uneven-aged stand structure, establishment of seedlings is usually necessary only about one year out of ten. Thus, if a 5-year cutting cycle is used, cutting to obtain regeneration is required only every other harvest.

Seedlings will usually develop under single-tree selection if after-cut density of overstory is reduced to 45 to 60 square feet of basal area per acre and site conditions are favorable. Structure in the merchantable component of the stand can be maintained by either the BDQ (basal area, maximum diameter, and constant ratio of number of trees in successive diameter classes—Q-factor) method (Farrar and Murphy 1989) or the guiding-diameter-limit method of volume regulation (Reynolds and others 1984).

The keys to successful selection management include: frequent harvesting at 3 to 10 year intervals; maintaining a relatively low overstory density of 60 to 75 square feet of pine basal area with only 40 to 55 square feet in sawlog-size trees; and periodic hardwood control. The combination of relatively low pine stocking and hardwood control permits an adequate amount of overhead and side light to reach the forest floor to promote growth and development of pine regeneration.

Some advantages of managing for natural regeneration with the selection cutting method are:

- Cut-over or understocked stands can be quickly rehabilitated.
- Periodic and flexible harvests are provided without interruption for stand regeneration.
- The stand is upgraded if fast-growing, high-quality trees are left to regenerate the stand.
- The stand is not as vulnerable to destruction by fire, biotic, or climatic agents.
- Production is concentrated on valuable sawtimber trees.
- The stand is more aesthetically pleasing to some people and provides more varied habitat for wildlife.

Disadvantages include:

- Some area-efficient management practices, such as prescribed burning and chemical treatments, are difficult to apply.
- Harvesting operations may be difficult and expensive.
- The method requires more management skill and supervision than other reproduction methods.

BASIC NATURAL STAND MANAGEMENT PRINCIPLES

Regardless of the method of reproduction employed, there must be an available seed source, and some site preparation and competition control is usually required. In addition, precommercial thinning in dense stands may be beneficial, and reproduction must be protected.

Available Seed Source

Regeneration by natural seeding requires an adequate, high-quality seed source on or adjacent to the area. Seeding characteristics of southern pines vary with species, physiographic region, climatic factors, and tree and stand conditions. Some of the seeding characteristics of southern pines are summarized in table 3.

Table 3. Seed crop frequency and dispersal for four southern pines for average sites and optimum number of seed-bearing trees.

Species	Frequency of good seed crops ¹	Period of peak seed fall	Effective distance of seed dispersal
	years		feet
Loblolly	2 to 4	late Oct.–Nov.	200 to 300
Shortleaf	3 to 6	Nov.	200 to 300
Longleaf	3 to 5	late Oct.–Nov.	60 to 70
Slash	3	Oct.	150 to 250

¹A good seed crop is considered to be an adequate number of seed to regenerate an area under average conditions. For loblolly and shortleaf pines, more than 80,000 sound seeds per acre is considered a good seed crop; 30,000 to 80,000 seeds per acre is an average crop, while less than 30,000 seeds per acre is considered marginal to poor (Baker 1982). About 50,000 seeds per acre are the minimum needed to adequately restock a prepared seedbed.

Several methods to estimate seed production of southern pines have been developed (Trousdel 1950, Wenger 1953, Grano 1957, Croker and Boyer 1975). The procedures provide estimates of the total number of cones and/or seeds per tree or per acre. Evidence of good, fair, or poor seed crops should be apparent by early summer; thus, the seedbed can be prepared prior to seedfall in early winter.

Site Preparation and Competition Control

Assuming there is an adequate seed crop, effective hardwood control and site preparation are the two most important elements required to obtain successful natural regeneration. These steps should be planned in advance and be carried out in a timely and effective manner. Inadequate control of competing vegetation—particularly midstory and overstory hardwoods—is probably the primary reason for most regeneration failures after seedling establishment.

Although some level of site preparation and hardwood control is usually required, the type and intensity of treatment depends on the species, local site and stand conditions, abundance of the expected seed crop, and the reproduction cutting method. Because of their large seeds, longleaf and slash pines require a seedbed of exposed mineral soil to achieve satisfactory seedling establishment. Loblolly and shortleaf pine seeds, on the other hand, do not require exposed mineral soil for germination and seedling establishment. As a result, adequate reproduction of these pines during years of bumper seed crops is usually obtained on many sites regardless of seedbed or site conditions. However, when the loblolly and shortleaf seed crop is light, seedbed preparation is necessary to ensure seed contact with mineral soil and to use the seed supply to the fullest extent. In most cases, soil disturbance from the logging operation is sufficient.

More intensive brush control is usually required on highly productive, moist sites than on drier, less productive soils. On these good sites, the competitive hardwoods, which often originate by sprouting, have the ability to overtop pine seedlings and occupy the site much faster than on poor sites.

In the South the methods of reproduction using natural regeneration in pine often result in too much stocking, rather than too little. The exception to this is longleaf; regeneration of this species is rarely excessive. Thus, to achieve optimal stocking levels for species other than longleaf, the intensity of the site preparation and competition control treatments prior to logging should be keyed to the abundance of the seed crop.

With even-aged methods of reproduction, a well-planned prescribed burning program in advance of the regeneration cut is the least expensive method of site preparation and competition control. Periodic prescribed burns not only reduce forest floor litter and ground vegetation, but also control some of the smaller hardwoods.

Midstory or overstory hardwoods should be harvested or treated with a suitable herbicide. On sites where pine regeneration is difficult to establish—because of droughty conditions or excessive litter and vegetative cover—some mechanical scarification may be required after logging. This can be accomplished by chopping, disking, or light scalping with a bulldozer.

After the seedlings have become established, additional control of competing hardwoods may be needed. If weed, brush, or vine growth is dense and vigorous, release of the young pines may be required within three years of establishment. This is best accomplished with herbicides. Once the reproduction reaches a size (usually 12 to 15 feet tall) where it is relatively safe from fire damage, prescribed burning may again be used to control the hardwoods.

With the selection method of uneven-aged silviculture, site preparation is achieved almost exclusively through the logging operation and by using chemicals to control the larger competing hardwoods (Reynolds and others 1984). If fully stocked uneven-aged stands are cut on relatively short cutting cycles of 3 to 10 years, the logging operation usually scarifies the site and retards the development of hardwood brush sufficiently to permit adequate regeneration.

Precommercial Thinning

With the exception of longleaf pine, too much reproduction is often obtained when managing for natural regeneration. This is a frequent occurrence with some of the even-aged cutting methods, particularly when a good seed crop follows intensive site and seedbed preparation. If the regenerated stand contains more than 5,000 stems per acre at 3 to 5 years of age, it should be precommercially thinned. Stands having between 1,500 and 5,000 stems per acre at age 3 to 5 years should be thinned only if it is estimated that live-crown ratios of dominants and codominants will be less than 35 percent at the time of the first commercial thinning. Precommercial thinning is critical for slash pine, which tends to stagnate in young, dense stands.

Mechanical thinning with a tractor-drawn rotary mower is one of the most practical methods for reducing density if the site is relatively free of high stumps and slash. Heavier equipment such as a rolling chopper must sometimes be used but thinning costs will increase. Stands should be thinned to leave 600 to 700 dominant stems per acre by mowing or chopping 8- to 12-foot-wide lanes with 1- to 2-foot-wide uncut strips.

Protection

Regenerated stands must be protected from wildfires, insects, and diseases. Loblolly, shortleaf, and slash pines are particularly susceptible to wildfire the first 6 to 10 years following establishment. With seed-tree and shelterwood methods, some insurance against complete loss by fire can be provided by retaining two to three seed trees per acre until the first pulpwood thinning. If the regeneration is lost to wildfire, there will still be a seed source available to regenerate the stand.

Insect and disease problems are not generally as common or devastating in naturally regenerated stands as in planted stands, but some insect and disease pests are possible. Seedling debarking weevils can cause a

problem in young natural regeneration near felled green timber. Pine tipmoths may cause problems in young open-grown stands such as in clearcut areas; but this insect is not usually a severe problem where some type of overstory or brush is intermingled with the reproduction. Fusiform rust is usually not as severe in natural stands as in plantations, but there may be some damage to susceptible species in high rust-hazard areas.

YIELD COMPARISONS

The debate over the relative merits of different silvicultural systems is as old as the forestry profession itself and will no doubt continue in response to new technical innovations, changing market and economic conditions, and public and social demands. Foresters dealing with southern pine forests have often discussed the choice between natural and artificial regeneration and even-aged and uneven-aged silviculture from the standpoint of economics and silviculture.

For loblolly and shortleaf pine, several forest management alternatives can be used in appropriate situations. Since foresters are primarily concerned with managing a renewable natural resource (trees), they should be aware of the yields of wood products that might reasonably be expected when considering such alternatives.

Yield comparisons for several silvicultural systems used for loblolly-shortleaf pine over the past 50 years are compiled in table 4. The comparisons include both even-aged and uneven-aged stands, a variety of methods of reproduction, and several levels of management intensity. The empirical yields are derived from seven long-term studies, involving six management situations, on similar sites in loblolly-shortleaf pine stands on the Upper Southern Coastal Plain of southern Arkansas and northern Louisiana.

Table 4. Empirical yields for loblolly-shortleaf pine stands after 36 growing seasons (adapted from Guldin and Baker 1988)

Stand	Yields per acre after 36 years			
	Total	Sawtimber		
	merch.		bd.ft.	bd.ft.
	cu.ft.	cu.ft.	Doyle	Intl.
1. Even-aged plantations				
a. Conventional silviculture ¹	6,000	2,700	10,400	17,700
b. Intensive silviculture ²	5,000	3,500	11,200	20,000
2. Even-aged natural stands				
a. Conventional silviculture ³	3,600	2,300	10,700	15,800
b. Intensive silviculture ¹	5,300	2,200	7,600	15,400
3. Uneven-aged natural stands				
a. Conventional silviculture ⁴	3,400	2,700	12,700	18,500
b. Intensive silviculture ⁵	4,100	3,000	15,500	20,400

¹Normal, periodic thinnings to 80 square feet of basal area per acre.

²Intensive, frequent thinnings and competition control to optimize sawlog production.

³No thinnings before age 36.

⁴Long cutting cycle (5 to 10 years) and moderate competition control.

⁵Short cutting cycle (1 to 5 years) and intensive competition control.

Total merchantable cubic-foot yields were highest for conventionally managed even-aged plantations; sawtimber cubic-foot yields were highest for intensively managed even-aged plantations and intensively managed uneven-aged stands. However, uneven-aged stands had higher board-foot sawtimber yields than the most productive even-aged stands, particularly in comparisons using the Doyle log rule. It is hypothesized that the even-aged plantations had higher cubic-foot yields because they were more fully stocked with trees of merchantable size. Conversely, the uneven-aged stands had higher board-foot yields because of the greater proportion and continuous supply of sawtimber basal area, especially in stems of large size, which can be developed using the selection cutting method.

It should be noted that the plantations in this compilation were established with woods-run planting stock, before the establishment of the contemporary practice of planting improved seedling stock selected for gains in volume production. Augmenting the standing volumes of these plantations by 20 percent to account for an assumed genetic gain would widen the discrepancy in yield of total merchantable volume at age 36 between plantations and uneven-aged stands and would probably equalize some of the disparity in sawtimber cubic-foot and board-foot volume. In addition, if yields could have been compared for a 50- to 60-year period, sawtimber production for the even-aged stands would probably more nearly equal that of uneven-aged stands.

CHALLENGES AND OPPORTUNITIES

Recent public involvement in forest planning activities has presented many challenges to silviculturists and resource managers of the National Forests in the South. Various special interest groups have appealed forest plans and forest management practices on some of the National Forests. Most of the appeals have centered around the issues of clearcutting and forest-type conversion on National Forest lands. This public outcry has made it necessary for silviculturists of the National Forest to adopt and use silvicultural systems that provide for non-timber values while allowing for the harvesting and utilization of this renewable natural resource.

Many of the appellants prefer that the National Forests discontinue clearcutting and adopt uneven-aged or selection management as an alternative. Some are also suggesting that various constraints be placed on the uneven-aged management system used by the National Forests. These constraints include: maintaining a hardwood component in the uneven-aged pine stand, using no herbicides to control competing vegetation, and maintaining at least 40 square feet of the older trees ("old-growth") in the stand. All three constraints are contrary to traditional uneven-aged management as developed and practiced in the southern pine forests.

To meet this challenge, we must educate the public regarding silvicultural alternatives that are biologically sound, and be knowledgeable of all available silvicultural alternatives that will permit multi-resource management of timber and non-timber commodities. We must also demonstrate ingenuity and flexibility in adapting these systems to provide desired resources.

With these challenges, we have several opportunities for improving the image and effectiveness of the Forest Service. We can demonstrate that professional foresters have, and can effectively use, many tools to manage and utilize our renewable timber resources while preserving, protecting, and providing non-timber values. In other words, we have the opportunity to practice the multiple-use concept adopted years ago by the Forest Service—"The National Forests shall provide the greatest good to the greatest number of people in the long run."

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ALTERNATIVE SILVICULTURAL SYSTEMS

THE CANADIAN PERSPECTIVE

Paul K. Diggle
Silviculture Branch
British Columbia Forest Service
Victoria, British Columbia¹

I noticed while preparing this paper that excepting for one other speaker today, I am the only one "honoured" by being allotted a 40 minute presentation – all the rest have only half that time. I also noted that I was scheduled for 11 a.m., a time I seem to remember as being a productivity peak from studies of daily work patterns. I am not sure whether the organizers really wanted to give me a workout – or whether they wanted to ensure that the audience would be wide awake and not likely to drift off to sleep. Perhaps both were intended.

Rather than "Alternative Silvicultural Systems - The Canadian Perspective", a better title might be "Alternative Silvicultural Systems - A Canadian's Perspective." My comments, of necessity, are going to relate primarily to B.C. where my experience and involvement have been so far.

I want to start with a very brief national overview, then a general perspective of forestry in B.C., leading into a specific discussion of alternative silvicultural systems in the province – where we have been, where we are and where we need to go.

We do not by any means have all of the problems solved. We are just beginning to seriously grapple with them but, by looking at what has happened elsewhere in the world, I hope we can learn constructively and avoid having to reinvent our own particular form of the wheel.

Not having a comparable Canadian counterpart to the U. S. Forest Service – our Canadian Forestry Service is basically a research organization with no mandate for forest land management, which is vested with the various provinces – it is not all that easy to obtain a quick update on alternative silvicultural systems across Canada. It has taken six speakers before me to deal with alternative systems in the United States.

¹ Presented at the 1989 National Silviculture Workshop, Petersburg, Alaska, July 10-13, 1989

In brief, however, in Eastern Canada there is a long tradition of partial cutting in Quebec, and also in Southern Ontario, in tolerant hardwood forests. I suspect that Ontario may, in the future, be using some alternative systems in the boreal forest as a result of a major lawsuit that has already been going on for a year in Thunder Bay and will take at least a second year to conclude. The suit has been brought against the Ontario Ministry of Natural Resources by an environmental coalition allied with Native Indian people. It is chiefly concerned over very large clearcuts, insufficient regeneration, and effects on other resources. With clearcuts up to 50,000 acres being cited, there is obvious reason for concern. In the three prairie provinces of Manitoba, Saskatchewan, and Alberta, there is no use of alternative silvicultural systems yet, though a trial is in progress looking at mixed spruce/aspen management.

That very brief overview now brings us to British Columbia. A few statistics are probably in order as many of you are not from our neighboring states of Alaska, Washington, Idaho, and Montana and we need to set the stage.

The B.C. Forest Service has under its jurisdiction over 200 million acres including some 113,563,000 acres of productive Crown forest land, out of a total provincial area of just over 234 million acres – or 366,255 square miles – more than Washington, Oregon, and California combined. From this forest land we harvest almost 50% of the national total of wood products.

In 1987-88, the annual cut from Crown forest land totalled 80 million cubic metres, or over 2.8 billion cubic feet. This volume was harvested from 590,000 acres, but only 10.5% of this area was harvested using some alternative silvicultural system. In the late 1970's and early 1980's, alternative silvicultural systems accounted

¹ Presented at the 1989 National Silviculture Workshop, Petersburg, Alaska, July 10-13, 1989.

for 15% to 17% of the area harvested, but since 1983 the proportion has been steadily declining. Unpublished totals for 1988-89 indicate a further drop in area down to only 8.7% of the total area harvested using some alternative system to clearcutting. This decline in use of alternative silvicultural systems contrasts strongly with rising public concern over clearcutting.

The forests of B.C. are, floristically, the most diverse of any Canadian province. They also occur on the most difficult topography with the greatest range of climate in the country. We don't have, in any way, a simple or small forest management situation. However, we are blessed, from a forest management viewpoint, by having an excellent ecological foundation on which to manage our forests. The entire province has been mapped on an ecosystem basis, with many silvicultural interpretations developed, though we are not finished yet.

Most of the 24 commercial tree species in B.C. are ecologically suited to clearcutting as a regeneration system. The main exceptions are interior dry-belt Douglas-fir, Western larch, and Ponderosa pine. These all occur in the south-central interior where most of the alternative silvicultural system usage takes place.

I will now briefly cover each of our six forest regions (administrative units) to outline what is happening and where, in the way of alternative systems.

The Vancouver Forest Region includes Vancouver Island, the Mainland coast up to Bella Coola, and the Queen Charlotte Islands. Clearcutting is by far the most prevalent silvicultural system. Only about 4,000 acres a year are harvested under some other system, the majority of which are commercial thinnings, mainly Douglas-fir and Western hemlock, pole cutting in Western redcedar and some *ad hoc* uneven-aged management which would probably fall into the category of selective logging in its true sense – that is, a tendency to high-grading. Helicopter logging of scattered high-value old-growth Douglas-fir on difficult terrain would fall into this category.

The Prince Rupert Region is the Mainland coast north of Bella Coola to the Alaska panhandle, and all the western half of the northern interior. It is an immense area with little access in the north. Less than 2,000 acres a year are harvested by other than clearcutting. There is a little commercial thinning – really a partial harvest – in previously unmanaged Lodgepole pine stands that are 40 to 60 years old. The objective of this thinning, which is usually followed by fertilization, is to accelerate the development of merchantable diameters to offset a future age-class gap, and to increase resistance to mountain pine beetle infestation. The other main component of

these 2,000 acres is the selective logging, by helicopter, of high value species such as Yellow cedar (*Chamaecyparis nootkatensis*) which is exported to Japan. This is essentially high-grading in otherwise inaccessible stands and there is no follow-up silviculture program due to excessive access costs.

The Prince George Region occupies the eastern half of the northern interior, across to the Alberta border. It too is a huge area, but with somewhat better access than the Prince Rupert Region. Almost all harvesting is by clearcutting in this region, usually less than 100 acres a year being harvested by some alternative system. This was not always the case. Back in the 1950's and early 1960's before markets developed for pulp logs and chips, only large sawlogs were considered merchantable – chiefly white or Engelmann spruce with some pole quality Western redcedar. Over 300,000 acres in the sub-boreal spruce biogeoclimatic zone were harvested with selection and strip cutting. There was a major regeneration failure in both cutting types, due in large part to severe brush problems and lack of suitable seedbeds. There was also extensive blowdown in the leave strips, not surprisingly, since spruce is a shallow-rooted species and there had been no previous management to increase wind firmness.

The failure of these systems led to substantial controversy, discussion in Royal Commission reports and an eventual change to almost nothing except clearcutting. I believe something parallel occurred in the 1930's and 1940's in the U.S. when selective logging was widely practised but then disappeared almost to the point of oblivion in the 1950's and 1960's.

The Cariboo and Kamloops Forest Regions cover the south-central and southern interior of the province from south of Prince George to the border with Washington. These two forest regions together account for the majority of alternative systems in all of B.C., some 40,000 to 50,000 acres per year. Three authentic alternative systems are distinctly practised in these two regions.

The seed tree system is used to some degree, particularly in the southern districts of the Kamloops Region. The species involved are Douglas-fir and Western larch. Some success has also been obtained with Lodgepole pine seed trees in conjunction with drag scarification to prepare a seedbed.

Shelterwoods in one form or another are quite widely used. One innovative example is in higher elevation ESSF zones. The Engelmann spruce and subalpine fir overstory is logged leaving the understory intact. This is mostly subalpine fir which is not preferred as a replacement crop species, so it is used as a nurse crop

for underplanted spruce, protecting it from temperature extremes and unseasonal frosts.

The third system, commonly known locally as "fallers choice," is essentially single tree selection where the faller chooses the trees to cut. The system was first implemented in the Kamloops Region in the early 1970's. Well-trained and supervised fallers have been able to carry out single tree selections satisfactorily without a separate marking system being necessary. A widespread problem with this system is not so much the system itself, but the extreme variation in the structure of the stands of dry-belt Douglas-fir themselves. Different Forest Service districts and different licensees all have their own methods of prescription development, none of them based on adequate growth and yield data or soundly based concepts of basal area or density in the different canopy layers. Almost all are characterized by excessive residual densities in the regeneration layers; densities that, in an area with 12 to 15 inches of annual precipitation, far exceed densities after spacing in even-aged coastal Douglas-fir plantations which receive three or four times the amount of rainfall. In general, though, this system is well received by the public, has benefits for wildlife, and is silviculturally appropriate as a regeneration system. We just need a major growth and yield program to enable the development of competent prescriptions to meet specific target stand requirements.

The final region is the Nelson Forest Region in the south-east of the province – bounded by the Rocky Mountains in the east and the Washington-Idaho-Montana borders in the south. In this region all alternative systems used elsewhere in the province are found. It is a region of great topographic and climatic variation, resulting in the most complex ecosystems in British Columbia. Some 9,000 to 10,000 acres a year are harvested under these alternative systems. The species involved are again primarily Douglas-fir and Western larch. The seed tree or a modified shelterwood system is widely practised, usually for larch. (But, if practice makes perfect, it could do with more practicing still, because it isn't perfect yet.) Joking aside, all too often the so-called seed trees are small larch, with only 15-20% live crown – trees that have enough trouble staying alive after the rest of the stand has been removed, without any real likelihood of producing a cone crop for a very long time. Some testing is being done, however, with girdling techniques developed in Idaho/Montana and I am hopeful that, if sufficiently vigorous trees are retained, that we will eventually be able to rely on the seed tree system for larch regeneration. In the meantime, underplanting often has to be relied upon to produce a new forest. As in the Cariboo and Kamloops Regions, objectives and prescriptions vary widely – as does the degree of success.

That must suffice for a review of what alternative systems are being used throughout the province.

I noted earlier that the percent of area harvested by alternative silvicultural systems has been declining for the last five or six years in spite of growing public concern over clearcutting. The reasons are several. One is economics – industry prefers clearcutting because of its apparent management simplicity and lower costs. Second is custom and experience – people are widely used to practising clearcutting. Another is current stand conditions. Most stands being logged are either old growth or have never been managed. They are unstable if partially harvested. A further reason is a growing concern by forest pathologists over the increasing occurrence of root rots in selection-logged stands.

However, one would have to be blind not to see the gradually rising tide of public concern over clearcutting and not to realize that we have a limited time to yet turn the tide before it becomes a flood. We have not had any clearcutting lawsuits in B.C. yet. Our political and judicial system is sufficiently different from yours that we may be able to avoid following in the U.S.'s footsteps where it seems so often now that resource management is being prescribed by the judiciary and not at the direction of the elected representatives of the people.

I have recently been directed to develop a discussion paper on alternative silviculture prescriptions and to propose a long-term strategy for their implementation and use in British Columbia.

A much-needed first step is to improve the execution of clearcutting with a real change in attitude needed on the part of most licensees. We have begun that change, in substantial part through a pre-harvest silviculture prescription process (PHSP) that I developed as a provincial program some five years ago. In 1988 it became mandatory for every proposed cutblock on Crown land, through new legislation. PHSP's enable a rational assessment of the most suitable silvicultural system well before logging. There is also a limit prescribed for the amount of site degradation allowable, based on site sensitivity ratings.

Even allowing for substantial improvement in clearcutting practices, there will still be an increasing pressure to use alternative systems. We have in B.C. the paradoxical situation of modern cities only a stone's throw from virtual wilderness. Urban populations with their facilities, the instant solution mentality, don't realize that forests take a longer time to grow, to change. The expectation of direction and rate of change in forestry is often unrealistic. We cannot convert old growth forests to well-managed second growth overnight – it has taken

European countries centuries to develop their manicured forests – in their own peculiar social and economic contexts. I want to avoid just transplanting practices from elsewhere. What we use must be locally relevant to our own situation.

There are three basic facets I see as fundamental to a long-term strategy. The first will be a retrospective review of silvicultural systems used in each region. Such an assessment will clearly be limited by the alternative systems used, their location and any data available. Typically, when different systems have been used to date, there has not been a lot of documentation. Proper analysis of these systems requires good data so interpretations can be expected to be limited.

While the retrospective review is proceeding, an assessment of the general public's concerns will be obtained through response to the discussion paper which will invite public input.

The second facet will be the establishment of a variety of alternative silvicultural system demonstration areas across a range of ecosystems and in strategic geographic areas. Some suitable areas already occur, but many new ones will have to be developed. Public communication and involvement must be integral to the development

of these areas which I would expect in substantial part to be guided by proposals emanating from the regional reviews. It will be important to have members of the public involved in both successful and unsuccessful alternative system demonstrations so that they can realize that alternative systems per se are not always better than clearcutting. The place of alternative systems needs public definition and recognition.

The final facet must be careful monitoring of both the biological and economic features of the systems tested. Although there are numerous texts on silvicultural systems, it is imperative that the evidence comes from local forests that have been treated with full public awareness and continuing accessibility and visibility. Monitoring will also be essential to assess economic feasibility, as opposed to biological possibilities. This will mean careful harvest planning and execution, with documentation of costs in a manner open for public review. Thus, industry can know the options, the public can understand the impact of any demands and the Forest Service will be able to judge what are reasonable solutions.

I have now looked at where we have been, where we are, and where I believe we should go. And that brings to an end this Canadian's perspective on alternative silvicultural systems for this morning.

UNEVEN-AGED MANAGEMENT: CONCERNS AND BIOLOGICAL REALITIES

Russell T. Graham
Intermountain Research Station, Forest Service
U.S. Department of Agriculture
Moscow, ID¹

ABSTRACT

Uneven-aged management is precisely defined, but the term is used to describe many nonclearcutting practices. Many practices called uneven-aged management are not biologically sound. Uneven-aged management may be used in the Northern Rocky Mountains, but biological principles must be maintained and the system used appropriately.

BASICS

Uneven-aged management or selection silviculture, composed of group and single tree methods, is a basic silviculture system available for forest management. Selection silviculture is a system for managing forest stands creating three or more distinct age classes, by removing single trees or small groups of trees (less than 2 acres in size) from forest stands.

There are several reports on procedures for applying uneven-aged silviculture (Graham and Smith 1983, Alexander and Edminster 1977, USDA Forest Service 1978). The basics are to develop stand parameters for: largest tree desired, residual basal area, diameter (age) distribution, and cutting cycle length. By altering these characteristics a variety of stands can be created. The decision to use group selection or individual selection, along with group size can alter the species mix.

CONCERNS

Selection systems are being promoted both within and out of the forestry profession as the answer to our management problems of the 1990's. The fundamentals of the selection system have been defined for many years (Hawley 1921), but the term "selection" is often used to describe any type of partial cutting. "There is no silvicultural system that is subject to a wider variety of interpretations than the selection system" (Smith 1962). It is defined in the *Forest Service Manual, Silvicultural Systems for the Major Forest Types of the United States*, *Society of American Foresters Terminology of Forest Science*, silviculture texts, forest plans,

conservation group newsletters, and newspapers. The definitions range from the recognized one of the forestry profession, to anything except clearcutting, keep green practices, and selective silviculture. The wide number of definitions have led to many misconceptions as to what uneven-aged management is and how it can be used. Forest management plans in both the public and private sector mandate the use of uneven-aged silviculture on thousands of acres and commit the silviculturist to a defined system whether it meets land management objectives or not. But because the recognized definition by the forestry profession is limiting, managers and silviculturists often misuse the term or redefine the term to their liking.

The management of public forests is now under more scrutiny and pressure than ever as we enter an era of renewed emphasis on the environment. Forest Plans for National Forests are being appealed, as are many timber sales, in an effort to change the type of harvesting used on National Forest lands. Because of this pressure to preserve the character of the forests, the Forest Service may try to reach their annual sell quantities by selectively harvesting high value, high volume trees from many acres with little visual or obvious environmental impact.

This method has been used before. In the early 1900's foresters in the Northern Rocky Mountains were directed by the Forest Service Manual to reserve 15 to 40 percent of the merchantable volume after harvesting. Planting was not to be planned except under conditions so unusual that natural regeneration could not be expected, and then only with the approval of the Forester (Chief of Forest Service). In addition, inferior species of low value would not be pushed on the market (USDA Forest Service 1928). These directions led to using species designation and diameter limits removing high valued, high volume western white pine (*Pinus monticola*), Douglas-fir (*Pseudotsuga menziesii*), ponderosa pine (*Pinus ponderosa*), western redcedar (*Thuja plicata*), and western larch (*Larix occidentalis*) from stands, leaving residual stands of western hemlock (*Tsuga heterophylla*), grand fir (*Abies grandis*), and lodgepole pine (*Pinus contorta*),

¹ Presented at the 1989 National Silviculture Workshop, Petersburg, Alaska, July 10-13, 1989.

and inferior western redcedar.

This selective silviculture practice continued for several years until the results indicated that thousands of acres of inferior, slow-growing stands were being created. Strip clearcuts, shelterwoods, and seed-tree cuts became the preferred regeneration methods for the Northern Rocky Mountains (Haig and others 1941).

Haig and others (1941) recommended clearcuts no wider than 400 feet and only on sheltered sites, but the practice of clearcutting became the norm and clearcuts became larger and site preparation and slash disposal often scarred the landscape. By the late 1960's the Forest Service found its timber management practices coming under increasing scrutiny, and legislation was passed dictating forest management practices. "Monongahela" and "Bitterroot" were the rallying calls of the 1970's for the environmental movement. For the 1990's they are "spotted owl" and "old growth." How the Forest Service reacts to the pressures from these issues is to be seen. The one inescapable fact is that we cannot sacrifice the biological principles of forestry.

SOME BIOLOGICAL PRINCIPLES OF NORTHERN ROCKY MOUNTAIN FORESTS

Northern Rocky Mountain forests are the most productive of the Interior Mountain West. Many have growth rates in excess of 200 ft³/ac/yr. They are diverse with 10 commercial conifer species. The species have a mix of shade tolerance, value, growth rates, and insect and disease resistance (Table 1). In addition to the conifers, the forests contain a rich mixture of hardwoods, shrubs, forbs, and grasses. With this diversity the forests are extremely valuable for timber, wildlife, water, recreation, and grazing.

Age and Diameter

Most forests of the Northern Rocky Mountains developed after fires, creating a mosaic of species and stands. The resulting stands are inherently even-aged (Haig and others 1941). On many sites a mix of shade tolerant and intolerant species regenerated, creating even-aged stands with four crown classes (Table 2). Light ground fires, windthrow, snow damage, and insect and disease outbreaks can cause openings that will encourage regeneration of shade tolerant species on some sites. These stands can develop into uneven-aged stands in the absence of fire and be similar in appearance to even-aged stands.

In designing or implementing uneven-aged systems, the assumption is often made that multisized diameters equal multiple ages. But just examining diameter

distributions can be misleading. The most common method of evaluating stands for the use in uneven-aged silviculture is to classify stands as having reverse "J" shaped diameter curves.

Often diameter distributions are not similar to age distributions. Using 68 randomly chosen stands containing a mix of Douglas-fir and ponderosa pine from northern Idaho, 65 percent of the stands were classified as having a reversed "J" shaped diameter distribution curve, only 30 percent according to age (Figure 1). Using stands containing shade tolerant species, a similar relationship existed (Figure 2).

The reason for the wide range of diameter and age curves in the stands is the variation in correlation between age and diameter in stands in northern Idaho. Using stands containing ponderosa pine and Douglas-fir, correlations between age and diameter ranged from -.75 to +.99 (Figure 3). A similar relationship existed using the more shade tolerant species (Figure 4). From these data it appears that grand fir (a preferred species for uneven-aged management) has poor correlation between age and diameter. Therefore, it is imperative that each stand be evaluated as to whether it is uneven-sized or uneven-aged. This relationship can also have important genetic implications, so that the fastest growing stems are not systematically removed from a stand when the oldest stems should be removed.

Stand Establishment

Foremost, the success of the uneven-aged management systems is predicated on the establishment of regeneration during each cutting cycle. Without regeneration the system will fail. Those species of the Northern Rocky Mountains that are adapted to fire germinate best on burned-over surfaces and mineral soils (Haig and others 1941). Fresh litter is usually a poor germination medium. Because moisture and oxygen are rarely limiting in the spring in the Northern Rocky Mountains, temperature is the most critical for germination. Soil temperatures over 51° F are needed and preferable between 71° and 81° F (Haig and others 1941). Therefore, stands managed with selection systems with multiple stories can keep soil temperatures low during the spring and also prevent surface moisture from wetting the forest floor to maintain favorable growing conditions during early root development. In addition, partial and full shade conditions (such as those created using uneven-aged systems) can restrict root growth making seedlings more susceptible to mortality from drought (Haig and others 1941). Therefore, shaded, undisturbed sites created with selection systems may not favor regeneration. If shade tolerant regeneration becomes established in shaded conditions, it can often grow for several years

with little or no crown development. Special care is needed to culture these trees into desirable crop trees by timely release.

Stand Culture

In a selection system, cultural treatments are required at each entry to develop the desired stand structure. Most often this requires the release of seedling and sapling sized trees.

The effectiveness of releasing seedlings and saplings from competition is highly variable. Subalpine fir appears to respond to release at ages up to 175 years if adequate tree crowns are maintained. Other species such as hemlock respond poorly to release with high mortality and slow growth rates. Indian paint fungus (*Echinodontium tinctorium*) can have high infection levels on western hemlock if branches are suppressed for over 40 years (McCaughy and Ferguson 1988).

Grand fir responds favorably to release if crown ratios are over 40 percent and trees are less than 30 years. Younger western redcedar respond favorably to release if tree crowns are full. Slow growing western redcedar and grand fir both have poor response to release (McCaughy and Ferguson 1988). The more moderately shade tolerant western white pine responds poorly to release at ages over 30 years (Graham 1988).

Therefore, age and tree condition determine the ability of trees to respond to release. Long intervals between entries in a selection system allowing crowns to shorten, or calling old, small diameter trees with poor crowns desirable regeneration are not biologically sound practices.

Stand Development

Understory regeneration height growth can be depressed by residual overstories. The growth of western white pine can be adversely affected with overwood densities as low as 60 ft² of basal area. At an overwood density of 150 ft² the loss of height growth would be unacceptable (Figure 5). Tree canopies over grand fir, Douglas-fir, or ponderosa pine would also affect tree growth to differing amounts. The stand parameters for uneven-aged stands to minimize growth loss have not been determined for the western forests.

Diseases and insects can be favored in multi-storied stands of shade tolerant species. Spruce budworm damage on grand fir and Douglas-fir make uneven-aged management questionable on many sites where these species are the desirable crop trees. Species susceptible to the root diseases *Armillaria* and *Phellinus* may also be unacceptable crop trees in selection systems. The incidence and damage caused by *Armillaria* can increase after harvesting. Mistletoe (*Arceuthobium*) infection is also favored by partial cutting that creates multi-storied stands. In addition to mortality related to insect and diseases, snow can be a major contributor to mortality, particularly with western hemlock (Table 3). This phenomenon can only increase when multi-storied stands are created with uneven-aged systems. After harvesting, heart rots usually increase because of logging damage. The exception is possibly western redcedar. Insects, foliage diseases, heart rots, root diseases, and snow damage make the use of uneven-aged systems a risky proposition on many sites in the Northern Rocky Mountains.

The action of partially cutting in mature stands can increase the probability of mortality (Figure 6). Harvesting in stands can cause foliage changes, root disturbance, bole damage, changes in water relations, and changes in nutrition. All these can cause stresses that contribute to mortality. Therefore, uneven-aged management will probably increase mortality rates in most applications.

CONCLUSIONS

Uneven-aged management can work in the Northern Rocky Mountains. The character of the forests and the silvics of the species present make the task formidable. If uneven-aged management is to be used, it should be used properly and the correct terms defining the system used. There are more than enough terms available for describing proper silvicultural practices.

Desired future forest conditions need to be described and the proper silvicultural system be used to meet those objectives. We should not dictate silvicultural systems in our management plans. And at no time should we sacrifice biological principles or misapply silvicultural systems in our management of the forests.

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Table 1: Relative rating of species in Northern Rocky Mountain forests. A rating of 1 indicates maximum expression of the property.

Property	Species ²									
	PP	DF	WL	LPP	GF	WWP	WRC	WH	ES	SAF
Seed Production	10	6	5	3	7	4	2	1	9	8
Seed Size	1	5	8	6	2	3	10	9	7	4
Seed Viability	4	7	5	2	1	8	9	6	3	10
Seed Predation	1	3	5	4	7	2	10	8	9	6
Shade Tolerance	8	6	10	9	3	7	1	2	5	4
Successional ³ Status	CS	CS	S	S	CS	S	C	C	S	C
Initial Growth	3	5	1	2	6	4	10	9	7	8
Volume Growth	7	5	3	6	2	1	10	9	4	8
Mature Height	4	5	1	10	3	2	9	7	6	8
Longevity	4	7	2	10	5	3	1	8	6	9
Resistance To:										
Root Disease	5	8	3	6	10	4	2	1	7	9
Heart Rots	5	7	1	2	9	3	6	10	4	8
Insects	6	10	5	8	4	7	1	2	3	9
Fire	2	3	1	5	4	6	7	9	8	10
Windthrow	3	8	1	9	6	4	2	5	10	7
Value	3	4	5	7	8	1	2	9	6	10

² PP=Ponderosa Pine, DF=Douglas-fir, WL=Western Larch, LPP=Lodgepole Pine, GF=Grand Fir, WWP=Western White Pine, WRC=Western Redcedar, WH=Western Hemlock, ES=Engelmann Spruce, SAF=Subalpine Fir.

³ C=Climax species, S=Seral Species

Table 2: Relative aggressiveness of individual species in stands 32 to 100 years old as measured by representation in different crown classes (Haig and others 1941).

Species	Dominant	Codominant	Intermediate	Suppressed	Basis Trees
	Percent				Number
Lodgepole	44	30	14	12	366
Larch	30	26	27	17	1,212
White Pine	16	19	27	38	8,924
Douglas-fir	8	15	25	52	1,089
Hemlock	5	9	27	59	2,812
Grand fir	2	6	14	78	3,854
Redcedar	0	2	10	88	1,445

Table 3. Mortality on sample plots in young second-growth western white pine stands, by species and causes (Haig and others 1941).

Cause of death	Western white pine	Western larch	Douglas- fir	Grand fir	Western hemlock	Lodge pole pine
	Percent					
Snow	25	50	28	39	80	42
Suppression	49	32	35	27	13	19
Injuries	5	8	11	8	2	6
Disease	7	0	6	3	0	9
Insects	1	1	4	6	1	21
Windthrow	1	2	1	0	1	3
Unknown	12	7	15	17	3	0
Total	100	100	100	100	100	100

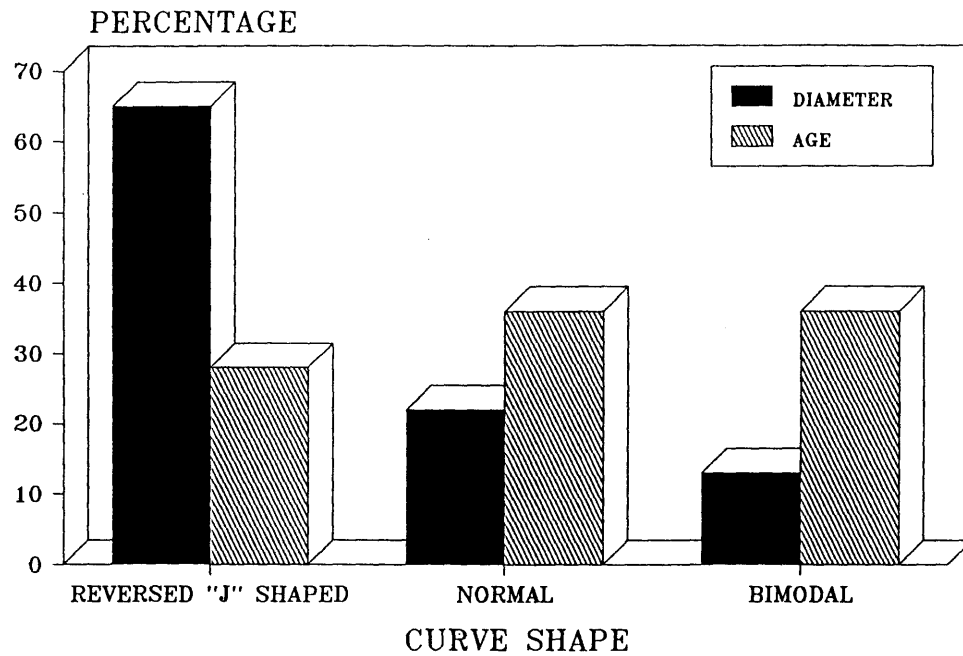


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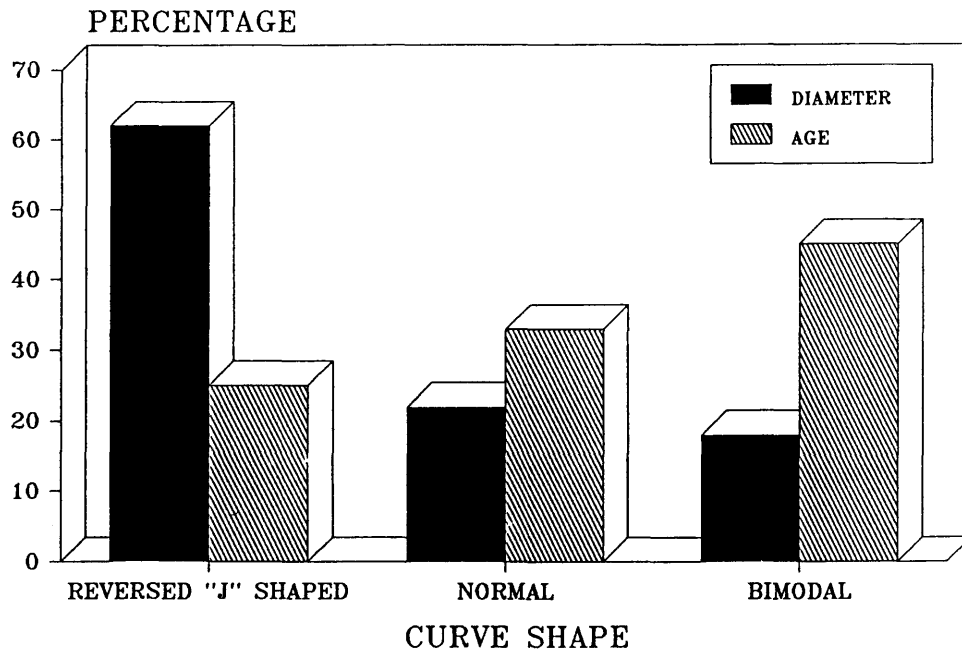


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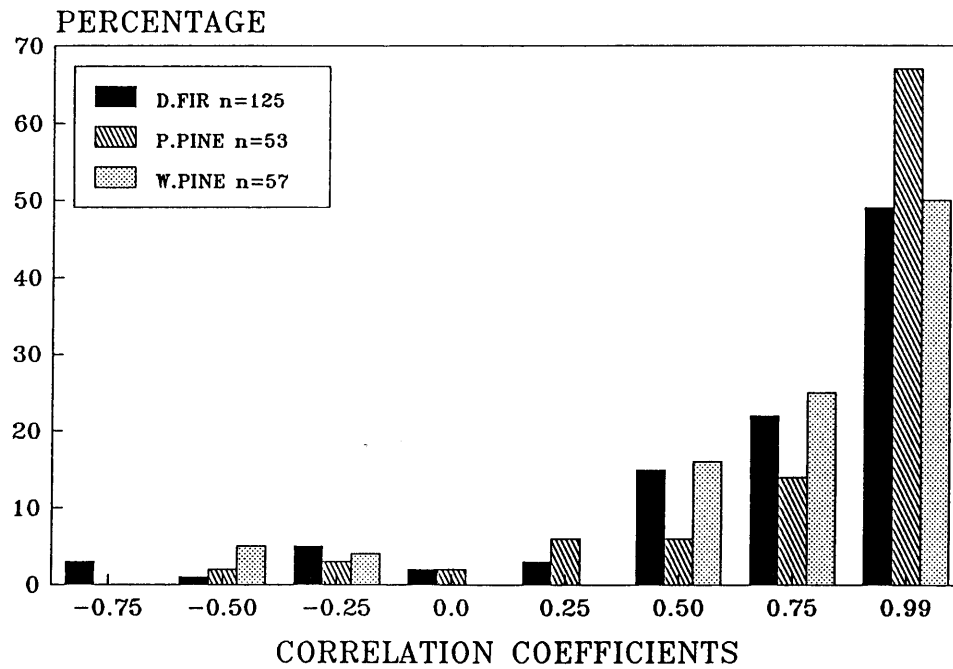


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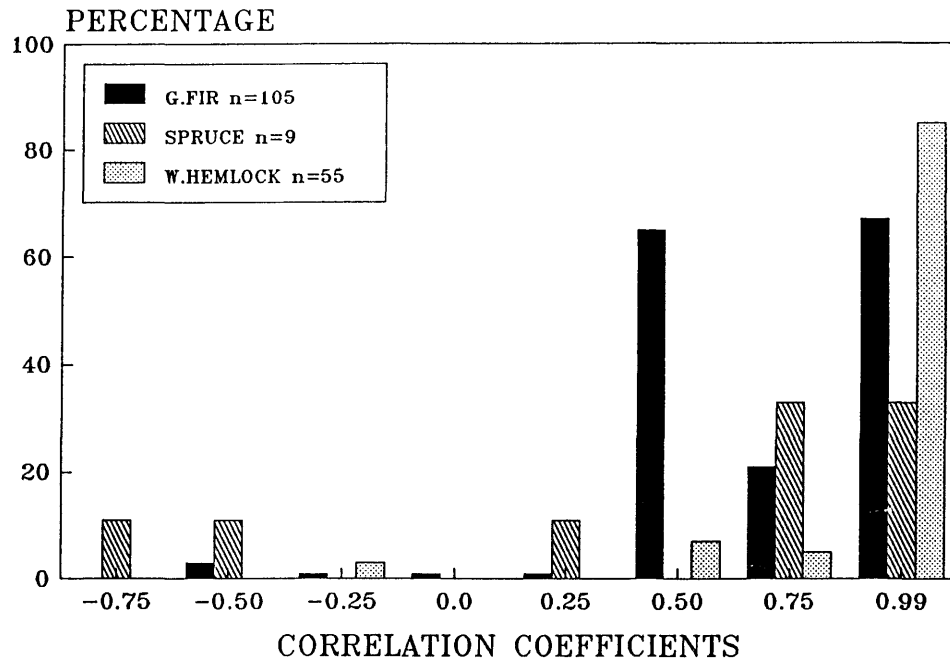


Figure 4. The percentage of stands having different correlations between age and diameter for grand fir, Engelmann spruce, and western hemlock for stands randomly selected from the Idaho Panhandle National Forests.

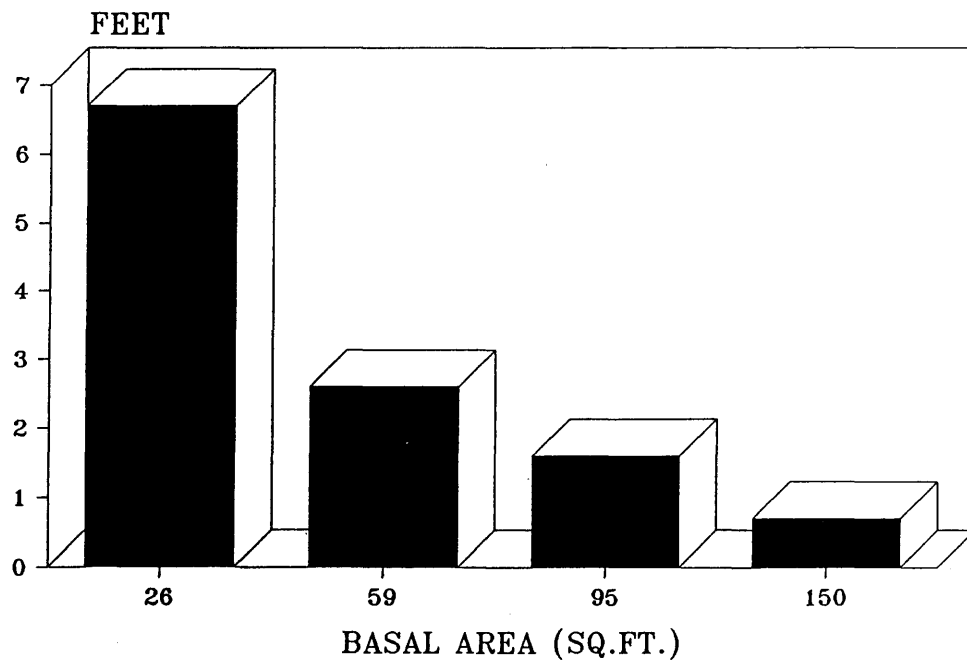


Figure 5. The relationship between 16-year-old regeneration height and overwood density for western white pine (Haig and others 1941).

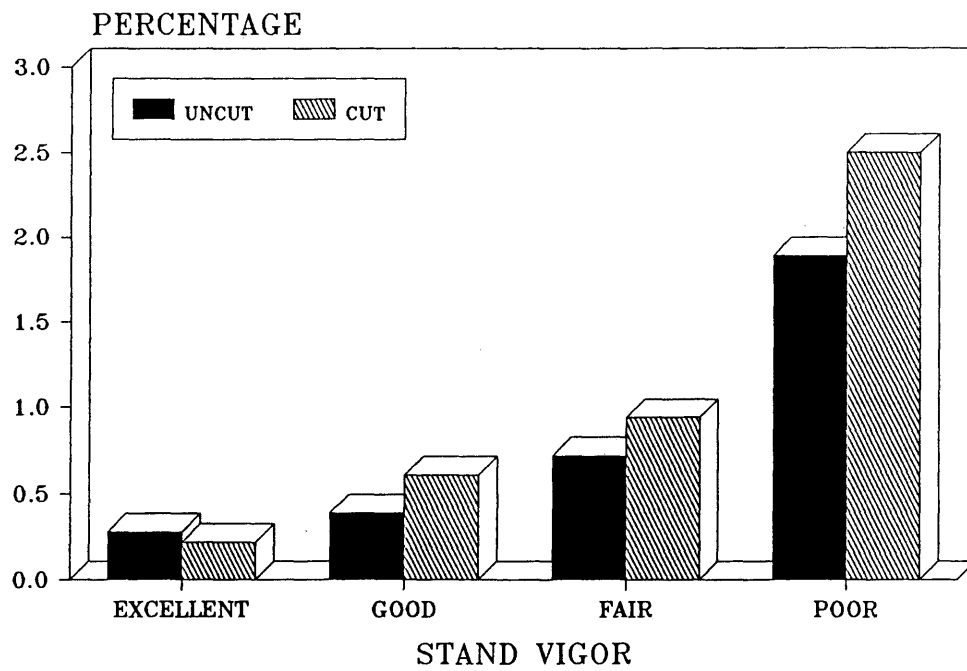


Figure 6. The annual mortality rate for western white pine in cut and uncut stands related to stand vigor (Graham 1980).

UNEVEN-AGE MANAGEMENT

MISCONCEPTIONS??

Glenn Jacobsen
Forest Silviculturist
Payette National Forest¹

ABSTRACT

Emphasis on uneven-age management is increasing with many landowners. Some of this emphasis is due to people opposed to clearcutting which they feel is linked to even-age management. Many people have their own definition of uneven-age management which is different from the Society of American Forester's definition. We can minimize confusion among individuals and groups if we stress the need to use the proper definition of uneven-age management.

INTRODUCTION

The past few years we have seen an increased emphasis on uneven-age management, both within and outside the Forest Service. The environmental community, many individuals from the timber industry, plus some Forest Service personnel advocate uneven-age management rather than even-age management. Much of this emphasis is generated by people opposed to clearcutting. In my travels in the Intermountain and Pacific Northwest area, I have talked to people interested in timber management and questioned their use of terminology related to uneven-age management terminology. Some industry people indicate they are using the uneven-age management system, yet when I quiz them about the application of uneven-age management they are generally dealing with even-age stand conditions. Misuse of the term "uneven-age" may have the effect of confusing people interested in Forest Service land management, and provide additional support to folks opposing even-age management. Timber stands in the west are generally created under even-age conditions.

TERMINOLOGY

There are a number of definitions for uneven-age management. The "Terminology of Forest Service Technology, Practice, and Products" book published by the Society of American Foresters (SAF) defines uneven-age as

applied to a stand in which there are considerable differences in age of trees and which three or more age classes are represented." The Forest Service definition adds to the SAF definition with "continuous high-forest cover, recurring regeneration of desirable species, and orderly growth and development of trees through a range of diameter or age classes to provide a sustained yield of forest products." Daniel, Helms, and Baker in their "Principles of Silviculture" book state "uneven-age forests have stands that are uneven-aged, where each stand may have at least three or four well-spaced age classes."

Definition of even-aged by the Society of American Foresters is applied to a "stand in which relatively small age differences exist between individual trees. The maximum difference in age permitted in an even-aged situation is usually 10 to 20 years, though where the stand will not be harvested until it is 100 to 200 years old, larger differences up to 25 percent of the rotation age may be allowed." The Forest Service definition is "a silvicultural system that produces stands in which all trees are about the same age; that, is the difference in age between trees forming the main crown canopy level will not exceed 20 percent of the rotation length."

Numerous variations of the above definitions can be found in various textbooks and bulletins.

MISCONCEPTIONS

I have heard numerous definitions of uneven-age management by various groups. These groups include Forest Service silviculturists, management team members, other Forest Service disciplines, forest industry personnel, and the public.

For example, silviculturists have used the following terms to describe uneven-age management:

-Uneven-aged with large groups - groups would average 3 acres in size.

¹ Presented at the 1989 National Silviculture Workshop, Petersburg, Alaska, July 10-13, 1989.

- High forest cover - an overstory is left.
- Green clearcuts - scattered crop and mostly non-crop trees left on a clearcut.
- High grading - high value species have been removed with usually the low value tolerant species remaining.
- Selective cutting - harvesting the high value species.
- Partial cutting - term tied to anything that is not a clearcut.
- Sanitation/Salvage - high value trees are harvested.
- Cull tree release - trees left after harvest are culls.
- Crappy silviculture - term used to describe stand conditions remaining with uneven-age management.

Management team members have referred to uneven-age management in these terms:

- Hide forest harvesting
- Answer to public opposition to clearcutting
- No specific definition whatsoever

Personnel in disciplines other than timber management have referred to uneven-age management as:

- High forest cover
- Not clearcutting
- Anything that is green
- Mixture of sizes even though all sizes are in one age class
- Species indifference - one species is as good as another

Timber industry folks use the following terms to describe uneven-age:

- Large tree harvest
- No planting necessary
- No precommercial thinning necessary
- Any harvest that benefits other users

Terms for uneven-age management by the general public are:

- Not clearcutting
- Visually pleasing
- Anything that benefits wildlife
- Anything that maintains green forests

There are probably additional terms used to describe uneven-age management that I have missed.

APPROACHES

When people talk about implementing uneven-age management, I hear different descriptions. One approach is termed "Not classical" which has no definition. Another approach is variations of even-age management. Uneven-age is defined to have a maximum group size of 2 acres, yet people describe uneven-age to include a group size of 3 acres plus. If there are no stand age goals, no intermediate stand treatment needs, and only short-term goals, uneven-age management is the answer for many people.

The approach to implementing an uneven-age management system is either group selection or individual tree selection. Group selection, with groups up to 2 acres in size, can be used to regenerate desirable species. The groups can be distributed over large areas. Individual tree selection would normally be used in riparian zones or campgrounds.

OUR ROLE

What's the answer? There are probably many different answers to improve the understanding of the proper use of the term uneven-age. I propose we consider doing the following:

-Question the use of terms used by personnel. This applies to meetings, tours, etc. Schedule a day on the ground and use an increment borer to determine age when you feel there is a misunderstanding.

-Use the Society of American Foresters definition of even-age and uneven-age when talking to people.

-Point out the need for correct terminology when dealing with people. This also includes Forest Service personnel.

-Use an increment borer to determine tree age. Do not relate age to size.

These items can be done in our day-to-day business. Most of us have opportunities to talk with both industry folks and management team members, and other disciplines in the Forest Service. I don't consider this a big time impact. The payoffs may be beneficial in regard to a clearer understanding of the silviculture systems used by industry, state, private, and federal landowners.

SUMMARY

Uneven-age management has a documented definition but many individuals and groups use definitions which

fit their perceptions. Improper definitions are increasing the misunderstandings of silviculture systems used by silviculturists, management team members, other disciplines, industry personnel and the general public. In many cases, uneven-age management is proposed to be practiced on even-age stands when in reality, variations of even-age management are being practiced on the ground. We can reduce this confusion of terms if we question the meaning of the terms people are using, refer to the Society of American Foresters definitions, and use an increment borer for age determination rather than relating age to size of a tree. The payoffs are a better understanding among peers, and an improved understanding by the general public when they hear terms used by forestry personnel.

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Terminology of Forest Science Technology Practice, and Products.

UNEVEN AGED MANAGEMENT AND LAND MANAGEMENT PLANNING: OBJECTIVES AND MONITORING

Walter H. Knapp
Pacific Northwest Region, Forest Service
U.S. Department of Agriculture
Portland, OR¹

The history of uneven-aged management in the Pacific Northwest Region has, like most histories, some surprises which are relevant today. The first revelation is that uneven-aged management was practiced for a time in the old-growth Douglas-fir forests west of the Cascade Mountain divide.

In 1934, the Pacific Northwest Regional Forester directed that clearcutting in the national forests west of the Cascades would be stopped. This edict cited a number of problems attributed to clearcutting, including danger from wildfire and loss of growing stock. Forest Supervisors were instructed to immediately begin a program of uneven-aged management, using some form of partial cutting.

From the vantage point of today, many silviculturists are not surprised that problems resulted when this policy was implemented. Much of the partial cutting in old-growth Douglas-fir forests resulted in net growth loss, windthrow, decay, logging damage, and even wastage of entire stands.

Yet some areas responded well to partial cutting, verifying a silvicultural truism: A blanket prescription will have holes in it. Treatments must be responsive not only to management objectives, but also to the silvical realities of stand structure and composition. And so it was not surprising that the policy was quietly abandoned in the postwar era, as the demand for timber from the national forests increased and intensive management became more prevalent. An interesting reading of this history can be found in the records of Leo Isaac, one of the premier research silviculturists of the time.²

Meanwhile, silvicultural practices on the national forests in eastern Oregon and Washington were evolving with their own histories – and surprises. Typical early harvests in the vast ponderosa pine forests of the region involved light partial cuttings, most often sanitation cuts designed to reduce susceptibility to insects and to salvage mortality.

Fire exclusion policies began in the early 1900's and continued throughout this era. The combination of light cutting and the virtual elimination of fire as a vegetation management tool resulted in ecological succession on a scale which was probably unprecedented in natural forests. Many areas which had been dominated by ponderosa pine gradually shifted to more tolerant conifers, notably Rocky Mountain Douglas-fir and white or grand fir.

With the shift in species composition came another series of surprises, different from those experienced on the westside national forests. The eastside mixed conifer forests had their own set of problems, particularly from insects and diseases. Losses due to defoliator insects and root rot have been on the upswing, and many fire behaviorists believe that the high intensity fires of recent years are at least partially due to the changes in stand structure and species composition.

Eastside forest managers recognized many of these problems during the 1970's, and began a shift away from the partial cutting and fire exclusion which had dominated the area for decades. This move coincided with an emphasis throughout the region on intensive timber management, mostly even-aged practices designed to produce high timber yields. By the early 1980's, all of the eastside national forests had developed management plans which not only showed traditional even-aged management as the predominant system, but in some cases prohibited the use of uneven-aged management except for minor applications. Not the least of the reasons for this shift away from partial cutting was the lack of quantifiable information on growth and yield in uneven aged systems.

THE MOVEMENT TO UNEVEN-AGED MANAGEMENT – THE PUBLIC SPEAKS

The 1980's can rightly be called the decade of Forest planning. As the draft forest plans were issued on eastside national forests, the public spoke. And the

¹ Presented at the 1989 National Silviculture Workshop, Petersburg, Alaska, July 10-13, 1989.

² Isaac, Leo A. 1956. Place of partial cutting in old-growth stands of the Douglas-fir region. Research Pap. No. 16, USDA Forest Service, Pacific Northwest Experiment Station, Portland, OR. 48p.

message was clear, do less clearcutting and more uneven-aged management. In the public mind, the objectives of management were superceded in importance by the methods used to achieve those objectives. For example, a wide range of methods are available for producing large, high quality ponderosa pine for lumber and visual quality, but many segments of the public concluded that such objectives could only be met with uneven-aged management. Variations of the shelterwood method and other even-aged methods were often not given full consideration. People often perceived that there were only two silvicultural choices – clearcutting at one extreme and uneven-aged management at the other.

In response, the national forests allocated large areas to uneven-aged management. Initially, these prescriptions were concentrated in the ponderosa pine forests, but later on, uneven-aged management was planned for mixed conifer forests as well. Planners were forced to address the uncertainties of growth and yield predictions, forest health, and other concerns associated with the system. In the forest plans, reasons given for choosing uneven-aged management included such diverse factors as the production of large logs for the timber industry, visual quality, wildlife habitat, protection of riparian areas, and public preference.

IMPLEMENTING AND MONITORING

Today silviculturists are faced with the challenge of carrying out the mandates of forest plans. They have expressed both concern and enthusiasm regarding the prospects of implementing uneven-aged management on a broad basis. Concerns are wide-ranging, and include ecological, economic, operational, and organizational factors.

ECOLOGICAL FACTORS

One of the more insidious aspects of uneven-aged management, natural succession and the tendency to lose desirable early seral species from the stand, has already been discussed. When coupled with fire exclusion, the result in some areas could well be unhealthy, unproductive forests. Strong intervention through management would be needed.

OPERATIONAL AND ECONOMIC FACTORS

As with any new endeavor or shift in management, there are formidable operational and economic factors to resolve. Training of silviculturists and technicians is an immediate need. In addition, we will need to

provide for continuity of the uneven-aged silvicultural prescription through time; the intent and pathway to the future desired forest condition will need to be clear to those who follow. We will need consistency in application of uneven-aged management, so that specific silvicultural techniques are widely understood and applied. Operational feasibility cannot be ignored; consideration for logging and transportation systems must be integral.

ORGANIZATIONAL FACTORS

Many of the procedural aspects of silviculture – stand inventory, activity reports, etc. – were developed with even-aged management in mind. They may not fit the needs of a broader range of methods which include activities under the umbrella of uneven-aged management. For example, in a 100 acre uneven-aged management unit, a minor amount of planting may be done at each entry. Planting may be scattered throughout the unit as well as concentrated in groups undergoing regeneration. The acreage planted is unknown, but it is certainly less than 100 acres. How is this work reported, credited, valued? In an era of targets and accountability, this is not a trivial question.

REGIONAL RESPONSE: COMMITTEE ON UNEVEN-AGED SILVICULTURE

Monitoring a complex system like uneven-aged management takes time. Response to treatment can not be measured in the short run. But in the near term, the Region has initiated an approach which combines traditional monitoring and the more subjective, professionally-based evaluations of silvicultural treatments. Specifically, we established a committee on uneven-aged silviculture. Objectives of the committee include (1) ensuring quality silviculture, (2) developing consistent definitions and practices, (3) increasing knowledge, and (4) identifying ways to meet multiple resource opportunities.

Members of the committee include the Forest Silviculturists on the eastside national forests, plus the Regional Silviculturist. Other specialists, such as ecologists, entomologists, pathologists, wildlife biologists, and landscape architects, will be involved as the work of the committee progresses.

The committee is directed to meet at least annually, and to visit at least one national forest in the field to view uneven-aged silviculture. An annual report to the Regional Forester will evaluate the status of training, growth and yield information, effects on forest

health, site quality, forest structure and composition, and resource implications.

MONITORING – QUANTITATIVE APPROACHES

The work of the committee is intended to supplement the conventional monitoring efforts on the national forests and not replace them. We will continue to use forest inventory plots, supplemented by managed stand surveys, to quantify results of management. These permanent plots will provide an invaluable long-term record which will be useful in future planning. We are hopeful that they will provide at least some of the answers to major questions on insect and disease impacts, wildlife habitat relationships, soils impacts, and long-term forest succession.

In addition to the standard plots, we are installing a series of growth and yield plots in cooperation with the Bend Forestry Sciences Laboratory. Plots have already been installed on 5 ranger districts on the Ochoco and Deschutes National Forests, and more replications are planned. These studies will provide valuable long-term information on treatment effects.

MONITORING – QUALITATIVE APPROACHES

Since many of the national forests adopted uneven-aged management in response to public comment, it would be logical to ask various interest groups if the application meets their needs, desires or objectives. In addition, we need to include professional evaluations of forest health and other considerations which will not soon be addressed through conventional quantitative monitoring.

SUMMARY

The forest plans call for application of uneven-aged management on a large scale. Many silviculturists and pest management specialists recognize this as a high-risk endeavor because of the lack of information and the potential for serious problems with forest health and stand succession. Yet many other resource specialists and certain segments of the public advocate the use of uneven-aged management to achieve their favored objectives.

During the coming years, we need to pay special attention to the things we can measure as well as those which we merely observe. The challenges are simple: Don't repeat the mistakes of the past, and leave a legacy of productive forests which meet a variety of resource objectives. The challenges are also difficult; they will tax the ingenuity and diligence of silviculturists for generations.

GENETIC EFFECTS OF EVEN-AGED AND UNEVEN-AGED SILVICULTURE

by

George E. Howe

Northern Region¹

ABSTRACT

The genetic consequences of any silvicultural treatment are describable as changes in gene frequencies resulting from selection, migration, mutation, and random genetic drift. The author considers even-aged and uneven-aged silviculture as changers of gene frequencies with eugenic, dysgenic, or neutral consequences depending on heritabilities, selection intensities, stand ancestry, and natural history. Even-aged silviculture inappropriately implemented may be dysgenic, but alternatives more frequently are dysgenic because of the way they are implemented. Uneven-aged silviculture is likely to be dysgenic in forests which enjoy little or no natural history of climatic climax. The author suggests strategies for even-aged and uneven-aged silviculture to avoid dysgenic consequences.

INTRODUCTION

One of the pressures we are responding to is the pressure to reduce even-aged silviculture. In response to this pressure, we see an honest effort to practice true uneven-aged silviculture. We also see some practices which are neither uneven-aged nor even-aged silviculture, but simply "get the cut out and leave some green trees on the site." My purpose is to compare and contrast the probable genetic effects of uneven-aged and even-aged silviculture and those other practices which are neither.

GENETIC PRINCIPLES AND PHENOMENA

Principles

Let me first review some genetic principles with you. How does man or nature change the genetic constitution

of plants or animals? We do so by changing gene frequencies through mutation, migration, genetic drift, or selection.

Mutation is the actual change in DNA or in chromosomes. Downs syndrome in humans is an example of chromosomal mutation caused by an extra chromosome 21.

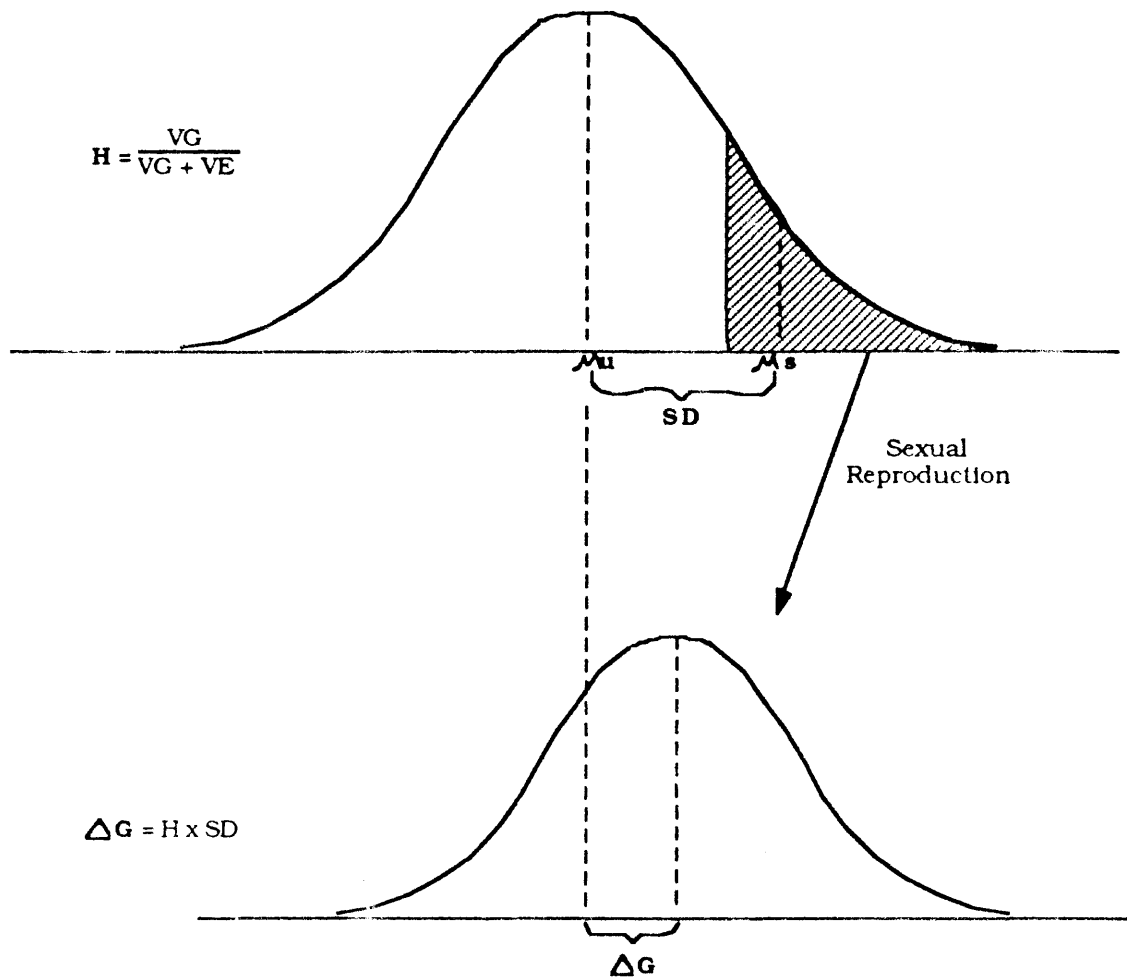
Migration is the movement of genes into or out of a population. The Selkirk caribou herd of northern Idaho (and southern British Columbia) is a small population of the caribou. Once in a while a young bull from another herd migrates into the Selkirk herd and, in doing so, brings new genes and combinations of genes into the Selkirk herd. Migration has some very important consequences, primarily beneficial, in small populations like that.

Genetic drift. These are changes in gene frequency due to chance alone. An example is small islands of trees surviving a major wildfire. As a result of chance selection of alleles coming from those few parent trees, there can be significant shifts in gene frequency in the offspring; that is, the offspring may exhibit a very different array of alleles than the original parents did.

Selection is changes in gene frequencies resulting from differential reproduction. We may have a population of individuals following a normal distribution and allow only a portion of the population to reproduce (Fig.1). If, as a result of that portion of the population reproducing, we get a shift of the mean in the offspring (Fig.1), we have practiced successful selection.

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Figure 1: Heritability, Selection Differential and Genetic Gain



- H** = Heritability
- VG** = Variation due to genes
- VE** = Variation due to environment
- SD** = Selection Differential
- μ_u = Mean of the unselected population
- μ_s = Mean of the selected population
- ΔG = Genetic Gain

Heritability is a measure of the ability of parents to transmit their genetic constitution to their offspring. I will limit my discussion to transmission via the sexual process. Heritability is the ratio of variation due to genes to total variation, which is variation due to genes plus variation due to the environment (Fig. 1). The important point here is that regardless of the amount of variation due to genes, heritability will tend to be small if variation due to environment is very large.

Now there are strongly, moderately, and weakly heritable traits, and it is important for silviculturists to recognize which traits fall into which categories. Diameter and height growth tend to be moderately to weakly heritable; specific gravity, disease susceptibility, and many insect susceptibilities tend to be strongly heritable; form traits tend to be moderately to strongly heritable (Spurr and Barnes, 1973; Howe and Raettig, 1985; Ledig and Smith, 1981; Zobel and Talbert, 1984; James, 1979).

Selection differential is simply the difference between the mean of the unselected population and the mean of the selected population (Fig. 1)—the measure of selection pressure. Selection differential obviously cannot be large if the population in which you are selecting is small.

Genetic gain. How much progress are we making genetically from generation to generation? Genetic gain is a product of heritability times selection differential (Fig. 1). Genetic gain obviously will be very small if either heritability or selection differential approaches zero.

Phenomena

Genetic gains from phenotypic selection. Forest geneticists have argued for decades about the virtue of intensive phenotypic (mass) selection in wild stands for achieving genetic gain. Jonathan Wright (and others) championed the point of view that variation due to genes was almost always *masked* by variation due to environment, while Bruce Zobel (and others) believed that careful phenotypic selection *would* achieve gain. In fact, the literature suggests they were both correct. Careful research has shown that intensive phenotypic selection often resulted in little or no measurable genetic gain (Morgenstern et al. 1975; Silen, 1977; review by Howe and Raettig, 1985; Samuel and Johnstone, 1979; Morgenstern and Mullin, 1988), while other careful research has shown such selection resulted in appreciable gain (Zobel and Talbert, 1984; Wilusz and Giertych, 1974; Ledig and Smith, 1981; review by Howe and Raettig, 1985).

Few of these researchers carefully described their stands and the environments in which they grew. Had they written such descriptions, I believe (from my experience) the following trends would have emerged:

1. The stands in which phenotypic selection proved fruitless were not of uniform age or spacing and grew on sites variable in aspect, elevation, soil, physiography and microsite; those in which phenotypic selection proved worthwhile were uniform in these influences (Dorman, 1969; Trimble and Seegrist, 1970). Age is probably the most important of these influences; those who measure growth and yield have shown that a tree established even 1 or 2 years ahead of its neighbor is not likely to be passed by its neighbor (Monserud, 1989). I believe uniformity in spacing to be the next most important influence.

2. Intensive phenotypic selection was rarely effective for achieving gain in weakly heritable traits.

The implication of these trends for natural regeneration is that if you are selecting desirable parents in a stand of uniform age and spacing, growing on a uniform site, expect some genetic gain for strongly (and maybe moderately) heritable traits, but not for weakly heritable traits. If you are dealing with a variable stand on a variable site, expect no genetic gain for any but the most strongly heritable traits.

Asymmetry of response to selection (Libby, 1989). None of the researchers cited in the preceding section studied the effects of selection for *poor* phenotypes of the traits they evaluated. For most of the traits we are interested in, selecting for poor phenotypes probably is not the flip side of the coin for selecting for desirable phenotypes for the same trait. Leaving poor phenotypes is apparently more effective for achieving genetic loss than leaving excellent phenotypes is for achieving genetic gain. Moreover, phenotypes poor in growth traits may be so due to damage in the past which is no longer detectable (Hoff and Steinhoff, 1984). The damage may have been from insects or disease and, as we have already said, disease susceptibility and many insect susceptibilities are likely strongly heritable (also see Heybroek et al, 1982; Hanover, 1975; Wagner and Tinus, 1985; Dix and Cunningham, 1984; Hoff, 1989; Hoff, 1988; Hoff, 1986; Hoff 1985; Goddard et al. 1975). There is meager but persuasive evidence for this phenomenon in the literature (Orr-Ewing, 1967²; Libby, 1989). (Canavera (1969), however, did not find that phenotypically inferior jack pine mother trees produced inferior offspring.)

² My own rank-correlation of Orr-Ewing's data suggested that the correlation Orr-Ewing found between phenotype of the parents and performance of the offspring families was mostly due to the correlation of minus-trees with offspring rather than of plus-trees with theirs.

GENETIC EFFECTS

Let's consider uneven-aged versus even-aged silviculture and their genetic effects (see especially Daniel, Helms and Baker, 1979).

Even-aged Silviculture

Shelterwood. I choose to start with even-aged silviculture and will first consider shelterwood cutting followed by natural regeneration. I think we can expect some authentic, although perhaps small, gain if we leave superior phenotypes for strongly heritable traits. An example is blister rust resistance in western white pine. I think we can expect no gain for leaving good phenotypes for moderately to weakly heritable traits such as height in Douglas-fir stands. I think we can expect some genetic loss from selection of poor phenotypes, and it may be a substantial loss for insect or disease resistance.

Some authors have suggested a possible increase in opportunity for inbreeding in shelterwood cutting or seed production areas (Daniel, Helms, and Baker, 1979, p. 362; Libby, pers. comm.), and we find mixed evidence of this in the literature (Neale, 1985; Neale and Adams, 1985; Coles and Fowler, 1976; Park and Fowler, 1984; LaFarge and Krause, 1981; Anon, 1962), although theoretical arguments are persuasive. The argument is that most forest stands tend to be composed of groups of families (Ledig and Smith, 1981; Daniel, Helms, and Baker, 1979 p. 362), and to whatever extent shelterwood cutting enhances opportunity for matings within families it increases opportunity for inbreeding.

Because of thorough pollen mixing and seed mixing at the time of dispersal, few Northern Rocky Mountain stands probably have strong family structure, and shelterwood cutting is unlikely to lead to inbreeding. The exception might be in heavy-seeded species. If you have reason to suspect that the stand consists of only a few families, you should either (1) regenerate to ensure dense initial stocking so that inbreds can be removed in thinnings (Friedman, 1986), or (2) supplement the natural regeneration by planting high quality planting stock. By all means, leave the best phenotypes and recognize that your selection for pest resistance is going to be more important than your selection for growth traits. Do not leave poor phenotypes for any traits (Dorman, 1969).

Seed tree cutting. Seed tree cutting may achieve higher gains than shelterwood cutting because selection differentials are higher. This is going to be especially true if the stand you are working with is truly even-aged and otherwise quite uniform. One could speculate that seed tree cutting may result in a higher frequency of selfing. That may be true, but selfs are quickly eliminated

(Friedman, 1986), most of them perhaps in the zygotic or pre-zygotic stage, and almost all of them probably before mature seed is formed (Yazdani et al. 1985). The literature, in fact, suggests that offspring from seed trees tend to be more heterozygous than offspring from adjacent, similar, uncut stands (Woods et al, 1986; Woods et al, 1980). To whatever extent the original stand was composed of family groups, seed tree cutting has likely broken those up. The seed trees are probably mated with individuals unrelated to themselves.

Seed tree cutting nonetheless will certainly create strong family structure, so do not regenerate at the end of the rotation by shelterwood cutting and do not regenerate more than two successive rotations by seed tree cutting. My recommendations for phenotypic selection are the same as for phenotypic selection in shelterwood cutting, except more emphatic.

Clearcutting followed by natural regeneration. This practice probably imposes neutral selection if the seed wall is representative of the original stand. You may have some opportunity for improving genetic quality of the offspring if you can make effective selections by roguing the seed wall, particularly for strongly heritable traits like rhabdoclone or western gall rust resistance. Such roguing obviously also will reduce the infection source.

Thinning in even-aged stands. If you are working with truly even-aged stands which are otherwise quite uniform, thinning provides an opportunity for real genetic gain by careful selection of leave trees in a series of thinnings (Bassman and Fins, 1988; Friedman, 1986; Ledig and Smith, 1981; Silen, 1988; Pawuk, 1988). It also provides opportunity for thinning out any inbreds that might be in the regeneration. I recommend you regenerate at higher densities than we are typically using now and plan for several thinnings, two or more.

Planting in even-aged silviculture. If your planting stock can be from well-managed seed orchards, it's guaranteed there won't be any inbreds in your planted regeneration. Moreover, if your seed orchard is from progeny tested and rogued seed orchards, you will achieve whatever gains have been brought about by selective breeding (Howe, et al., 1980). Planting also may offer you the opportunity of introducing better than local provenances, and they do exist. There are both elegant theoretical arguments and persuasive evidence from the literature that sometimes non-local provenances are better than local provenances in every way, including adaptation to the site (Stettler and Heilman, 1984; Stettler, 1986; Friedman, 1986).

Uneven-aged Silviculture

Let's move now to uneven-aged silviculture, that is, individual tree selection and group selection. Smith (1962) describes selection cutting as the harvest of the oldest and largest trees with some pre-determined diameter limit taken as the definition of the smallest trees old enough for such cutting. Of course, even if you are trying to do the best job you can, the temptation is always to take the best phenotypes. More frequently, selection cutting has been a euphemism for high grading.

Because of the impracticality of ascertaining the age of every tree potentially to be cut, foresters typically substitute diameter-limit cutting as a surrogate, but many authors are unequivocal in their criticism of diameter-limit cutting. Zobel and Talbert (1984) regard diameter-limit cutting as dysgenic and resulting in poorer quality, slower growing stands. They believe that dysgenic selection of even one generation may be undesirable for seed collected from such stands for planting, because nursery practices tend to encourage survival of genetically inferior seedlings which would have perished in nature (supported by Muona, et al., 1988). Maynard, Overton, and Johnson (1987) characterize diameter-limit cutting as follows:

"In terms of genetic consequences, diameter-limit cutting is like destroying the 1st, 2nd, and 3rd place finishers in every horse race, and putting the last place finishers out to stud!"

In my opinion, selection cutting can be correctly done only if: 1) your age classes are narrow, 2) you are sure you are cutting the oldest and largest trees within an age class and not cutting outstanding phenotypes in a younger age class, 3) you are also thinning out poor phenotypes in each age class each cutting cycle. The implication is that you need to know the age of each tree potentially to be cut. Is this really practical? Uneven-aged silviculture may also provide a great opportunity for inbreeding between a tree and its offspring or other close relative in a younger age class (Ledig and Smith, 1981).

If uneven-aged management were ever to successfully be practiced wholesale over large areas for long periods of time, it has the potential for quickly liquidating pioneer and early seral species (Zobel and Talbert, 1984). Uneven-aged management of this sort would be inconsistent with the ecology of virtually all Temperate forests, which recycle periodically, primarily by fire.

There are opportunities foregone by uneven-aged silviculture. The first is gain from phenotypic selection. It

is very difficult (perhaps impossible) to select superior genotypes by selecting superior phenotypes in uneven-aged stands (Zobel and Talbert, 1984). Also, to whatever extent uneven-aged

management relies on natural regeneration, you are foregoing the benefits from planting I listed earlier.

Smith (1962) summarizes the genetic consequences of selection cutting by saying, "If there is any method of cutting that is likely to reduce the productivity of the forest by eliminating good genotypes, it is the selection method. It is probably difficult to avoid, even under intensive application of the method."

What do I conclude from all of this? First of all, uneven-aged management is much more likely to result in dysgenic selection than even-aged management. Dysgenic selection is certainly more subtle but in the long run much more damaging than the purported "evils" it is intended to replace. Smith (1962,

p. 242) states, "The harm that can be done by dysgenic cutting is...greater than the benefits to be gained by eugenic cutting." Second, it is far easier to liquidate species with uneven-aged management because, while a shade-tolerant climax species readily can be a component of even-aged stands, an intolerant pioneer species generally cannot be a component of uneven-aged stands. Third, planting is much less likely to be used in uneven-aged stands, so the benefits of planting, particularly the planting of genetically improved stock, are foregone. Fourth, the principal ecological determinants of genetic quality are breeding system, floral morphology, life cycle, timing of reproduction, and successional stage (Loveless and Hamrick, 1984). Any management strategy which drastically alters any of these determinants for several generations is likely to adversely affect genetic constitution and should be avoided. Tinkering with a smooth-running engine is far more likely to deteriorate than to improve its functioning.

For example, fire cannot be tolerated in managed uneven-aged stands, and the ecological virtue of excluding fire indefinitely in most Temperate forests is highly dubious (Howe, 1976; Habeck and Mutch, 1973). Perhaps other genetic attributes of forests are associated with ecosystem recycling such as the association of genetic variation with life-history traits (Hamrick, Linhart, and Mitton, 1979) or the apparent association between vigor and heterozygosity (Mitton, 1988).

Other Practices

I consider here all cutting practices which leave the site occupied predominantly by poor phenotypes which contribute substantially to the regeneration. I believe such

practices to be genetically dangerous, almost always leading to dysgenic consequences either from asymmetry of response to selection or from the leaving of trees carrying genes for increased susceptibility to insects or disease. The concern about dysgenic consequences of high grading is not an idle one. Forest productivity is the seat of a 3-legged stool supported by good soil, good climate, and good genes. The examples of genetically degraded populations around the world are numerous. An example from the United States is the population of Monterey pine on the Monterey Peninsula. While the trees there are certainly scenic in their limbiness, short stature and sweeping trunks, they hardly could be considered useful for ship masts, yet their ancestors were so tall and straight that they were prized as masts for the sailing ships of California's Spanish settlers. The stands were repeatedly high graded, leaving only genetically inferior trees, and the productivity of those stands has been reduced as surely as it would have been had the quality of climate or soils been degraded.

Some argue (indeed, I myself have argued) that if a poor phenotype is the result exclusively of suppression, then the tree may be no poorer genetically than outstanding phenotypes. I think the argument is weak. I believe suppression is most often due to age differences—even small age differences. But the manager can be assured that poor phenotypes are younger only if the trees are bored, a measurement I see little willingness to take. Moreover, in many stands, we have little or no history of past pest attack, so poor phenotypes may in fact be due to such attacks which we cannot now detect, and such trees likely carry more than their share of genes for susceptibility to the pest. Whenever suppression is *not* due to age differences (i.e., all trees in the stand originated in the same year), then one is certainly unwise leaving the trees unable to keep up, because the uniformity (in age) increases the probability that the poor performance has a strong genetic component.

RECOMMENDATIONS

What are my recommendations from all of this? First of all, we must understand the natural history of the ecosystems we are working with. We must develop a multi-rotation management strategy that mimics this natural history. If we do this, in my opinion, for Temperate forests, even-aged management will be the predominant choice.

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FOREST HEALTH THROUGH SILVICULTURE

David G. Holland, Acting Director
State and Private Forestry
Intermountain Region, USFS¹

The public, Members of Congress, and government policy makers perceive a need to more adequately protect the health of the nation's forests. This perception is caused by reports of forest insect outbreaks and disease epidemics, air pollution and acid rain effects, falling forest productivity, and large catastrophe forest fires. Declining forest health is seen as part of the pending environmental crisis associated with global warming, species elimination, tropical deforestation, toxic waste, and ocean pollution. In addition, the failure of resource managers and environmentalists to reach accord on natural resource management objectives, the disagreement among specialists about strategies for achieving resource management objectives, and the inability or reluctance of government officials to confirm or refute speculation on environmental degradation has eroded public confidence that we as scientists can recognize, or more importantly, prevent environmental crisis.

Our forests are dynamic systems undergoing continuous change. Historically, naturally occurring wildfires, windstorms, floods, drought, and pest outbreaks destroyed old forests and created conditions favorable for new forests. Native American peoples used fire to prevent forest encroachment or improve wildlife habitat. Land clearing and forest use activities of European settlers accelerated impacts on the forests. Today, man's actions within and outside the forests, and naturally occurring events are having dramatic and far-reaching effects on forest health.

In recent years forests in Western North America have been subjected to large outbreaks of mountain pine beetle that are killing millions of lodgepole and ponderosa pines, millions of acres of defoliation by western spruce budworm, and large suppression efforts against gypsy moth and spruce budworm. The large forest fires of 1987 and 1988, that were exacerbated in part by pest killed trees, also contributed to the public's perception of declining forest health. We are beginning to hear and see more reports about global warming and the green house effect and the possible disastrous consequences this may have for forests in the future.

The primary reason for the increased emphasis on forest health is the intensive use of forests by the public. The public is seeing the forests more closely than they ever

have. They have more leisure time for recreational activities. People are using the forests for a myriad of activities and in the process they see many dead and dying trees. They are expressing their concerns to us and to elected officials.

So, what is a healthy forest? A healthy forest exists when biotic and abiotic influences on the forest do not prevent the accomplishment of the management objectives for that unit either now or in the future. A wide variety of forest conditions can exist within the context of this definition, and meet the Nation's needs from its' forests.

One of the basic obligations of forestry is protection and enhancement of the health of the forests entrusted to our care. Gifford Pinchot stated "the purpose of forestry, then, is to make the forest produce the largest possible amount of whatever crop or service will be most useful, and keep on producing it for generation after generation of men and trees." Or more succinctly, as stated in the the Forest Service mission statement: "Caring for the Land and Serving People."

My charge today is to discuss the topic of forest health through silviculture. Yet, let me ask you as Foresters and scientists, does the term "silviculture" empower you and the public we serve with visions of healthy forests? I don't think so. Recent surveys, described in Coufal's 1989 article in the Journal of Forestry, asks practicing foresters if "forest management" means "timber management" - 97 percent of the respondents disagreed. But, when asked if "silviculture is the art and practice of controlling the establishment, composition, and growth of stands for wood production"-66 percent agreed.

This seems to be a dilemma...is silviculture synonymous with wood production?

Are the claims of the new environmental newspaper in the Pacific Northwest, the "Inner Voice" valid...that is, and I quote: "The stubborn, get-the-cut-out mindset we tend to embrace... blinds us to the actual destructive results of our action. We only see what we want to see"? When I talk to co-workers about this subject, it is almost universally agreed that we are, in fact, over cutting.

¹ Presented at the 1989 National Silviculture Workshop, Petersburg, Alaska, July 10-13, 1989.

We are being challenged, so let's define our responsibility. Are we changing in an atmosphere where our base fundamentals—the concepts of sustained yield, allowable cut, cut effects, and evenflow—are little more than “myths” as stated by Marion Clawson in his recent *Journal of Forestry* interview.

Changes will continue to occur rapidly; we need to clearly define the meaning of silviculture and its application in ensuring vegetation cover to support multimanagement objectives. You as Silviculturists, don't need to wear “black hats,” but rather, define your role and implement it.

Silviculture needs to be broadly described as the application of cultural practices to define the characteristics of a healthy forest, determine present forest conditions, develop an understanding of how to achieve the long-term health of forest resources, monitor and interpret the dynamics of forest ecosystems.

A variety of standards can be used to describe a healthy Forest. Each standard must be based upon specific management objectives for that forested area. The appearance of a forest can vary markedly depending upon the stand management objectives. The desired vegetation condition for a stand devoted solely to short rotations to maximize wood fiber production might be to have no dead trees, all trees would be evenly spaced and growing rapidly. The desired vegetation condition for a stand containing a campground might be to have a variety of trees and other vegetation. Some of the trees may have peculiar deformities caused by pests that give them a unique appearance. Another stand with multiple objectives of timber production, dispersed recreation, and wildlife habitat enhancement may contain several dead and dying trees, including some deliberately created snags for cavity nesting birds and small mammals. All of these stands could be considered healthy if the condition of the vegetation supports the management objectives. Dead and dying trees are not always reliable indicators of deteriorating forest health. In the case of the stand with the multiple objectives, the dead and dying trees can contribute to long term health by providing habitat and food for birds and predatory insects that feed on destructive insects, by providing shelter for rodents that feed on and disseminate beneficial fungi, and recycling nutrients back into the site. As stated earlier, a forest is unhealthy when the biotic and abiotic pests, such as insects, fungi, depleted soil nutrients, and pollutants do not allow attainment of the management objectives.

The Forest Service has prepared a strategic plan for enhancing and maintaining forest health through silviculture and integrated forest pest management. Vegeta-

tion management was identified as the key to creating enduring forest conditions capable of meeting resource management goals.

The strategic plan recognizes the need to institutionalize an Agency commitment to vegetation management as an enduring means of ensuring healthy forests. Forest resource management is a long-term process. The management scheme must be structured and designed to allow realistic integration of pest occurrence, effects and treatment with the dynamics of forest stand growth, and management objectives. The issue at hand is not how much and when forest pests will affect management opportunities, but what the objectives are for a specific forest or forested area. If managers can describe the vegetation needed to achieve the land use objectives for an area, then you as silviculturists, or architects for Vegetation management, can develop the plan to ensure attainment of the desired vegetation condition.

For example, during a review of timber management activities on the Bridger-Teton National Forest in the summer of 1985, a primary objective frequently encountered was to maintain cover for big game. The public and wildlife interests wanted to maintain entire drainages in forest cover, and part of their concern involved road building and opening of drainages to hunting pressure. There seemed to be a desire to “hold” old-growth stands indefinitely, even without planned regeneration of the stands.

These forests are part of a dynamic, everchanging ecosystem with a kaleidoscope of changing vegetation, a myriad of insects and diseases, and historic fire regimes. To maintain such forests as they are today is totally unrealistic. In areas not designated for timber harvesting, fire should be reinstituted into these ecosystems. Fire management plans should be designed for these areas and integrate forest succession, insect and disease dynamics, and fire ecology. The most obvious indications of the irrationality of holding these stands are the widespread incidence of mountain pine beetle, spruce budworm, dwarf mistletoe, comandra rust, root rots, and dying aspen clones. In many forests, lodgepole pine has been replaced by the more tolerant spruce and fir, and even these species are dying and falling to the ground, creating surface fuels that will eventually burn, usually under rather severe fire weather and with catastrophic results. We then stand to lose tens of thousands of acres of cover at once as we did in the 1988 Yellowstone Fires.

A better understanding of the interactions between the ecosystem and the mountain pine beetle can be gained from a review of forest inventory data gathered before the recent beetle outbreaks on the Targhee and Ashley National Forests. The outbreak on the Targhee NF in

southeastern Idaho, started in the early 1960s and lasted 15 years. At the beginning of the outbreak, 88 percent of the lodgepole pine was 60 to 120 years old and resulted from large replacement fires in the late 1870s. The Targhee sustained tremendous losses to the mountain pine beetle, thus limiting management alternatives to salvaging and regenerating dead forested areas. And, in 1988 large portions of these beetle-killed forest stands contributed to the intensity of the Yellowstone Fires.

The Ashley National Forest experienced an outbreak from 1979 to 1985, which killed the majority of lodgepole pine more than five inches in diameter up to 10,300 feet in elevation. Only eight percent of the lodgepole pine was less than 80 years old before the outbreak. Silvicultural opportunities have been severely limited to salvage and regeneration.

These examples illustrate the fallacy of "holding" old-growth stands, and the need to better plan, through silvicultural treatment our strategies for achieving future desired conditions. In lodgepole pine on the Targhee and Ashley NF's we need to create a larger distribution in age classes, and encourage more species diversity and age distribution to enhance wildlife and recreation.

The forest insects and diseases that are most important today include western spruce budworm, mountain pine beetle, dwarf mistletoes, and root diseases. Insects and diseases affecting plantations and cones and seeds will become more important in the near future. Damage caused by animals, such as mountain beavers, pocket gophers, and deer is becoming increasingly important in plantations.

Some past forest management practices have inadvertently encouraged pests to increase. The long term effectiveness of fire management programs has contributed to a large increase in acreage of spruce budworm susceptible host type. Past selective harvesting of the more economically valuable ponderosa pine from mixed conifer stands has had the same effect. There is evidence that repeated selection and salvage harvesting has contributed to an increase in root disease mortality. Inability to economically harvest large areas of overmature lodgepole has contributed to outbreaks of mountain pine beetle.

Yet, many of our forest management practices have clearly contributed to declining losses to pests. Increased road access has allowed for prompt treatment of bark beetle threatened trees, as well as being a tremendous aid in reducing response time to fires. Thinning and harvesting have significantly reduced losses caused by dwarf mistletoes, stem decays, and bark beetles. Suppression of defoliator outbreaks of spruce budworm and Douglas-fir tussock moth with insecticides have pre-

vented large losses. The important point here is we have learned from these experiences. We need to use these experiences to avoid creating similar problems in the future. A case in point, we need to avoid practicing uneven-age management in large areas of mixed conifer stands in the interior west because this will make the present problems of spruce budworm, root diseases, and dwarf mistletoes considerable worse. This practice perpetuates the stand conditions most favorable for these pests.

Although the actual loss of wood fiber to pests has declined since the 1950's, the losses now being experienced are more important in terms of disrupting forest management objectives. Timber harvesting is still important, however, other activities such as recreation, have taken on much more important roles than in the past. The public has the leisure time and money to allow them to use the forests. The public is demanding multiple use of public forests. The health of forests affects their capacity to produce the full gamut of goods, services and values the public is expecting.

We are making substantial financial investments in forests now. As you as foresters are aware, site preparation, planting of genetically improved seedlings, management of competing vegetation, fertilization, and precommercial thinning all have large costs. Each tree in a managed stand represents a lot more investment than a comparable tree 30 years ago.

What is the future state of forest health? We can't expect to make all our customers happy in the future. Losses of trees to forest pests will continue to decrease steadily in response to forest management actions. Dead and dying trees and pest outbreaks will be readily visible to the public. Losses to pests will be disruptive to management objectives, especially as forests are increasingly allocated to specific or predominant uses. The size of most pest outbreaks will decline as more areas are subjected to silvicultural treatments. Intensity of damage caused by most outbreaks will also be lessened because vigorously growing trees will be able to tolerate pest attacks more effectively than trees in unmanaged stands.

The point is, it has taken centuries of natural processes and decades of interaction with man to create the present forest conditions. It will take decades of deliberate silvicultural actions to achieve large improvements in forest health. The best long term approach to achieving improved forest health is through cultural treatments.

Factors that erode long-term forest health considerations originate from perspectives that focus only on near-term profits, consider only short-term impacts, and pursue

reactive management. Short-term productivity targets are achieved at the expense of long-term protection of biological diversity, ecosystem stability and resilience, and sustained forest productivity.

The forest health issue confronting us involves both technology and philosophy. Accelerated application of available technology; broadened emphasis on research and technology development, particularly on vegetation models that fully accommodate the impacts of pests,

fire, and drought; and the Agency's commitment to long-term forest health monitoring are needed. A commitment to enhancing and maintaining forest health is essential if the Forest Service, as a natural resource management agency, is to be in tune with public expectations and priorities. And you, as silviculturists, are the architects for designing the plan toward more healthy forests.

SILVICULTURE AND FOREST HEALTH

ON THE PIKE AND SAN ISABEL NATIONAL FOREST

by

Christi Gordon
Forest Silviculturist
Pike and San Isabel National Forest¹

In the Rocky Mountain Region, the exclusion of wildfire and low level of vegetation management has resulted in a preponderance of mature, often even-aged forests. Approximately 55 percent of the forested acres in the Region are over 100 years of age. Less than 1 percent of all forested land is harvested on an annual basis, primarily due to relatively low site productivities and forest product values. This situation presents challenges for successful integration and implementation of the forest health, recreation and wildlife/fisheries initiatives. Vegetation management strategies on the Pike and San Isabel National Forest will illustrate the application of forest health principles in high use recreation areas.

TIMBER MANAGEMENT SETTING

The Pike and San Isabel National Forest is situated on the Front Range of Colorado, east of the Continental Divide. The eastern portion of the Forest interfaces with the cities of Denver, Colorado Springs and Pueblo, Colorado (total population 2 million). Forested land generally occurs within an elevation range of 6,500 to 11,500 feet.

Typical of most forests in the Rocky Mountain Region, the Pike and San Isabel is a minor timber producing forest. Site productivity on the Forest is relatively low, primarily due to: 1) low precipitation; 2) short growing season due to high elevation; and 3) shallow, low fertility soils. Timber

quality cannot satisfy the needs of the traditional lumber market. Most forest products are fuelwood or specialty items such as sawn ties and rough sawn lumber.

EARLY MANAGEMENT ON THE PIKE AND SAN ISABEL NATIONAL FORESTS

In the latter part of the nineteenth century, vegetation management on the Forest was limited to partial cutting or clearcutting to provide mine props for the booming minerals industry and construction products for growing towns on the Front Range. Harvest occurred primarily in the more accessible ponderosa pine (*Pinus ponderosa*) type, rather than the lodgepole pine (*Pinus contorta*), spruce/fir (*Picea engelmannii*/*Abies lasiocarpa*), aspen (*Populus tremuloides*) and Douglas-fir (*Pseudotsuga menziesii*) types. In the 1950's and early 1960's, a spruce bark beetle (*Dendroctonus rufipennis*) epidemic decimated several thousand acres of Engelmann spruce on the Forest. Most of the affected spruce was situated in high alpine basins which were too wet and steep for conventional ground-lead logging systems. Forest managers clearcut accessible spruce/fir, primarily in the Wet Mountains of the San Carlos Ranger District.

Due to wildfire suppression and low levels of silvicultural treatment, large areas of the Forest have achieved a mature vegetative condition. Table 1 depicts a distribution and age class summary for each forest type on the Forest.

TABLE 1

Forest Type	Percent of Available Timberland	Percent Mature to Overmature
Ponderosa pine	23 %	75 %
Douglas-fir	32	75
Spruce/fir	24	55
Lodgepole pine	12	69
Aspen	9	75

¹ Presented at the 1989 National Silviculture Workshop, Petersburg, Alaska, July 10-13, 1989.

Forest-wide, more than 80 percent of the 1,503,289 available timberland acres are over 80 years of age. Due to a preponderance of older, even-aged stands, the Forest has a moderately high susceptibility to insect and disease problems. Dwarf mistletoe is common in lodgepole pine and ponderosa pine. A mountain pine beetle epidemic in the early 1980's caused moderately heavy mortality on the Pike National Forest. A spruce budworm epidemic in the mid-1980's devastated much of the Douglas-fir and is still a problem in localized areas on the Forest. Aspen mortality is increasing, primarily due to various stem rots.

CHANGING MANAGEMENT ON THE PIKE AND SAN ISABEL NATIONAL FOREST

During land management planning in the early 1980's, the Forest Management Team identified the need to implement a larger scale vegetation management program to meet multi-resource management goals and objectives. The Forest Plan, approved in 1983, projected an inter-related array of multiple resource outputs for the 50 year planning period. Vegetation management was recognized as an integral part of Forest Plan implementation. For the first decade, the Forest Plan specified an annual allowable sale quantity of 26 MMBF, which corresponds to an annual commercial harvest of 10,240 acres. Commercial harvest, supplemented by 600 acres of timber stand improvement (TSI), would affect less than 2 percent of the 581,550 suited acres per year. The Forest Plan projected a 42 MMBF base sale schedule and 5,000 acre TSI level by the end of the 50 year planning period.

The Forest Plan provided the impetus for integration of silviculture with multiple resource management. The recent forest health, recreation and wildlife/fisheries initiatives have strengthened the integrated approach to natural resource management on the Forest. The remainder of this paper will focus on two examples of silvicultural strategies employed to integrate silviculture with forest pest management principles in recreation emphasis areas.

PONDEROSA PINE AND MIXED CONIFER: DISTRIBUTION AND ECOLOGY

Ponderosa pine occupies 349,772 acres, or 23 percent of the available timberland on the Forest. Ponderosa pine often occurs in pure stands and is considered climax on sites near the center of its elevational range. On the Pike National Forest, it often occurs with Douglas-fir in mixed conifer stands. Douglas-fir is the climax species on these sites, and will eventually replace seral ponderosa pine in the long-term absence of disturbance. Natural regeneration of ponderosa pine requires a good

seed crop, favorable seedbed conditions and ample moisture the spring following seed fall. These three conditions coincide infrequently on the Forest. Fire suppression has resulted in less favorable ponderosa pine seedbed conditions, due to accumulation of organic litter and establishment of competitive vegetation. Between 1960 and 1980, the acreage occupied by ponderosa pine decreased by 27 percent, while the acreage occupied by Douglas-fir increased by 24 percent. Wildfire suppression has favored establishment of Douglas-fir, which is less resistant to fire than ponderosa pine. The shift to Douglas-fir increases stand and forest susceptibility to western spruce budworm (*Choristoneura occidentalis*). The budworm thrives under conditions found on the Forest: warm, dry Douglas-fir habitat types where the host Douglas-fir is abundant (Carlson and Wulf, 1989).

SILVICULTURAL STRATEGIES IN THE MIXED CONIFER TYPE

The primary silvicultural strategies employed to reduce susceptibility to spruce budworm included (Ronco, et al, 1983): 1) emphasize even-aged silvicultural systems to promote single-storied stand structure. Managers emphasized the shelterwood system because natural regeneration was likely within five years after final harvest; and 2) favor non-host species. In mixed conifer stands, ponderosa pine was the favored leave tree species during commercial thinnings and seed cuts. Underburns were prescribed after seed cuts to favor establishment of ponderosa pine.

The Russell Ridge Timber Sale on the South Platte Ranger District of the Pike National Forest will be used to illustrate the integration of silviculture and forest pest management principles to meet resource objectives in an urban interface area. The South Platte Ranger Station is located in Lakewood, Colorado, within the Denver Metropolitan Area (population 1.5 million). The Russell Ridge Timber Sale is located approximately 40 miles southwest of Denver, in a portion of the district with a management emphasis on rural and roaded-natural recreation opportunities. The sale area includes part of a developed motorcycle trail network consisting of 115 miles of trail. Year-round recreational use is heavy.

The sale area is characterized by even-aged, mixed conifer stands 80 to 90 years of age, situated within the Douglas-fir/kinnikinnick-common juniper (*Pseudotsuga menziesii*/*Arctostaphylos adenotricha*-*Juniperus communis*) plant association (Johnston, 1987). Soils are predominantly sandy loams. Average site index is 60/100 (Alexander). Although most stands on drier sites are typed as ponderosa pine, Douglas-fir is a substantial stand component and is the major tree species in the understory.

In the early 1980's, a mountain pine beetle (*Dendroctonus ponderosae*) infestation occurred in the vicinity of Russell Ridge. The Interdisciplinary Team responsible for sale design recognized the need to improve forest health to meet visual quality and other objectives over time. The primary silvicultural goal was to reduce susceptibility to mountain pine beetle, spruce budworm and wildfire. Silvicultural prescriptions included two-step shelterwood and commercial thinning to improve stand vigor. Ponderosa pine was the favored species in both prescriptions.

The shelterwood prescription specified prescribed fire to accomplish site preparation for natural regeneration. The primary objectives of the underburn were three-fold: 1) prepare seedbed favorable for establishment of ponderosa pine regeneration; 2) reduce competition from established Douglas-fir regeneration; and 3) reduce fire hazard, particularly near private land. The prescriptions also specified commercial thinnings at ages 50 and 70 to maintain stand vigor.

The selected density management regime for stands prescribed for commercial thinning would maintain stands in the low risk category for mountain pine beetle (Stevens, et al, 1980). The Rocky Mountain Growth and Yield Model (RMYLD) was used to analyze density management regimes.

Most silvicultural treatments were successfully completed before the Russell Ridge Timber Sale defaulted in 1988 due to purchaser financial difficulties. The remainder of the sale was re-offered in 1989, but did not sell at currently high advertised rates. The remainder of the sale will be combined with a nearby large sale scheduled for offer in fiscal year 1992.

LODGEPOLE PINE: DISTRIBUTION AND ECOLOGY

Lodgepole pine occupies about 178,197 acres, or 12 percent of the 1,503,289 available timberland acres. This species primarily occurs in even-aged, single-storied stands of fire origin. Lodgepole is usually seral in the long-term absence of major disturbance. Cones are typically serotinous. After disturbance, natural regeneration normally results in overstocking which necessitates pre-commercial thinning. Mature to overmature stands occupy approximately 123,164 acres, or 69 percent of the lodgepole pine type. Dwarf mistletoe infects more than 50 percent of lodgepole pine stands. Most stands on the Forest exhibit reduced growth, relative to average lodgepole pine site potential. The high percentage of older, slow growing stands has increased susceptibility to mountain pine beetle.

SILVICULTURAL STRATEGIES IN THE LODGEPOLE PINE TYPE

The primary silvicultural strategy used for mountain pine beetle control is the creation of a mosaic of age and size classes by clearcutting (Amman, et al, 1977). Opportunities to favor species not susceptible to mountain pine beetle are few and are generally limited to areas with high resource value such as developed recreation sites. Stand replacement and sanitation are common silvicultural practices applied to stands infested with dwarf mistletoe.

Lodgepole pine is a low value commercial species, due to its characteristic small diameters. As a result, vegetation management to meet multi-resource objectives in accessible areas is typically accomplished by the public fuelwood program.

Vegetation management in the Turquoise Lake Recreation Area will illustrate an integrated approach to lodgepole pine management. In the early 1980's, forest managers on the Leadville Ranger District commenced plans for further development of Turquoise Lake. A brief description of this high use recreation area and determination of the need for long-term vegetation management follows.

The Turquoise Lake Recreation Area is located 3 miles west of Leadville, Colorado. The area encompasses approximately 800 acres adjacent to the eastern edge of Turquoise Lake. The area includes six developed campgrounds, two picnic areas, two boat ramps and one group picnic/campground. Recreational use is estimated at over 200,000 recreation visitor days. All of the developed campgrounds are within 1/4 mile of Turquoise Lake. The lake is partially visible from most sites. The presence of the lake and its visibility are considered major factors in the popularity of the area.

The recreation area is characterized by rolling topography and soils of glacial origin. At an average elevation of 9,900 feet, the predominant vegetation is lodgepole pine, in dense, single-storied, even-aged stands 100 to 110 years of age. Understory vegetation is generally limited to small quantities of common juniper, kinnikinnick, spruce/fir regeneration in moister microsites and lodgepole pine regeneration in small openings. Average site index is 60/100 (Alexander).

In 1981, forest managers performed an intensive vegetation survey within the recreation area using the 6-class dwarf mistletoe rating system developed by Hawksworth (1977). This survey revealed that half the acreage was infected with dwarf mistletoe, with some of the heaviest concentrations occurring in the developed recreation

sites. Most stands were rated as moderate risk for mountain pine beetle, using the stand susceptibility predictor developed by Amman and others (1977). Stands typically had sparse understories and minimal regeneration. The relatively poor vegetative condition prompted forest managers to form an Interdisciplinary Team to develop a long-term vegetation management plan for the recreation area. The Team was comprised of several multi-resource District staff, the Landscape Architect, Silviculturist and Wildlife Biologist from the Supervisor's Office, and a Plant Pathologist and Entomologist from the Regional Office.

The primary goal of the ID Team was to develop a long-range vegetation management program to produce and maintain the desired vegetative character. First, the Team expressed the desired vegetative character in terms of vegetation management goals, summarized as follows:

Vegetation management goals for developed recreation sites:

1. -maintain a forested, natural appearing character
2. -develop an uneven-aged stand structure
3. -underplant shade tolerant conifers and shrubs to promote mixed species composition, screening between camp sites and foot travel control
4. -maintain stocking at desirable levels
5. -provide vistas and framed views from specified camp sites
6. -reduce dwarf mistletoe infection severity and improve stand vigor

Vegetation management goals for undeveloped sites:

1. -maintain even-aged stand structure
2. -rely on natural regeneration of lodgepole pine
3. -reduce dwarf mistletoe infection and maintain vigor of new stands

Next, the ID Team subdivided the recreation area into twelve treatment areas and provided general treatment specifications for each area. A variation of the individual tree selection method was prescribed for developed recreation sites. Prescription specifications included a 15 year cutting cycle for all developed sites, as well as residual basal area goals and broad diameter class distribution goals tailored for each situation. A "planned pattern harvest" system was developed for implementation of the clearcut regeneration method in undeveloped areas. Four treatment entries were displayed on a photomap and incorporated into the vegetation management plan. The first entry was designed to reduce or eliminate as much of the dwarf mistletoe infection as would be consistent with recreation objectives. The Team recommended a clearcut size of 1 to 20 acres and a treatment re-entry period of 15 to 20 years.

The first entry has been successfully completed in two-thirds of the undeveloped areas and two of the campgrounds. Pest management and recreation funds were pooled to construct interpretive trails and publish informational brochures to explain vegetation management goals for the recreation area to forest visitors. In 1989, individual tree selection was initiated in the Molly Brown Campground. The silvicultural prescription specifies underplanting Engelmann spruce seedlings on moister microsites outside foot travel lanes and transplanting several adapted species to enhance vegetative diversity and screening between camp sites. District personnel plan to adopt the Plant-a-Tree program to defray costs and encourage public involvement in natural resource management.

FUTURE MANAGEMENT ON THE PIKE AND SAN ISABEL NATIONAL FOREST

The commercial sale program on the Forest was at its peak in FY 1985, when the Forest sold 31 MMBF. Since FY 1987, the ability of the Forest to sell commercial sales has steadily diminished, resulting in a reduced volume offer each year. In 1989, the Forest will offer 11 MMBF, less than half of the allowable sale quantity of 26 MMBF. Reasons for this "no bid" sale situation include: 1) sharp decrease in the demand for public fuelwood in the late 1980's; 2) loss of contributed funds for timber sale road construction in 1987; 3) lack of specialty product processing facilities, such as waferboard or excelsior plants, within reasonable haul distance; and 4) local purchasers will not buy sales at currently high advertised rates.

If this trend continues, Forest Plan implementation at current multi-resource output levels will be improbable. Forest managers have reduced their reliance on the commercial sale program by focusing on more non-commercial vegetative treatments. The Forest is currently planning several non-commercial vegetation management projects which will emphasize new partnerships, increased public involvement and cost-sharing opportunities.

The Pike and San Isabel is scheduled to begin revision of the Forest Plan in fiscal year 1992. Forest managers predict that a timber re-inventory and a new forest products demand analysis will result in a reduction in the allowable sale quantity during Forest Plan revision. The Forest Management Team must consider opportunities to improve marketing of forest products and to increase non-commercial vegetative treatments. The Team must determine cost effective vegetative treatment output levels which can effectively integrate the forest

health, recreation and wildlife/fisheries initiatives. Approval of the revised Forest Plan will solidify management direction for vegetation management on the Pike and San Isabel National Forest.

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DO TIMBER MANAGEMENT OPERATIONS DEGRADE LONG-TERM PRODUCTIVITY?

A RESEARCH AND NATIONAL FOREST SYSTEM COOPERATIVE STUDY

Robert F. Powers
Pacific Southwest Forest and Range Experiment Station
USDA Forest Service
Redding, California¹

ABSTRACT

Sustaining or enhancing site quality and productivity is an ethical responsibility of public land managers and a legal requirement of the USDA Forest Service. Evidence from around the world suggests that certain forest practices can degrade site quality, and that causes are tied to losses in total soil porosity and site organic matter. In response to requirements of the National Forest Management Act of 1976, each Forest Service Region is developing soil quality monitoring standards that detect long-term declines in potential productivity. Yet, these standards often are based on professional judgment because conclusive research results are scarce. Are such standards adequate? Forest Service Research and National Forest Systems are cooperating to answer this and other questions through a coordinated series of long-term field experiments. This study will be piloted in Regions 5 and 8.

INTRODUCTION

Sustaining long-term site productivity (the wood-growing capacity of commercial forests) is a fundamental goal of forest management in North America and a legal requirement of the USDA Forest Service. The success of our variety of silvicultural systems depends on sustaining each site's capacity to grow vegetation. In some highly productive wood growing areas—particularly on industrial lands—rotation lengths are shortening, logging residue use is rising, and site preparation practices are intensifying. Mechanized harvesting methods involving larger, more mobile machinery are used increasingly to extract whole trees. Removing more biomass accelerates the loss of nutrients and organic materials important to soil resiliency and microbial activity. Use of heavy equipment to prepare sites for regeneration raises the risk of soil compaction. The sparse and fragmented scientific evidence, reviewed by Powers and others (in press), suggests that these and other practices may threaten long-term soil productivity (the soil component of site productivity). Thus, sustained, long-term soil productivity of forest land is emerging as a legal and scientific issue.

As the world's largest forest management and forest research agency, the Forest Service has lead responsibility for resolving this matter.

BACKGROUND

Historical Records

Clearly, activities leading to slope failure and loss of the soil mantle degrade site quality and need not be detailed here. But are less dramatic activities also destructive? Because of confounding factors, direct evidence is rare in the United States, but long-term records from the southern hemisphere and central Europe indicate site productivity has been lowered by certain management practices affecting the soil.

In the pumice region of New Zealand, displacing surface soil and organic materials into windrows during site preparation led to a 16-percent loss in volume growth of a *Pinus radiata* D. Don plantation at 7 years (Ballard 1978), and a 30-percent loss after 17 years (Dyck and Beets 1987). Similar results have been cited in the United States. Fox and others (1989) reported 23-percent reductions in volume growth for a 25-year-old plantation of *P. taeda* L. growing on a fine-textured soil in North Carolina. Powers and others (1988) found that nitrogen (N) stress was common in *P. ponderosa* Dougl. ex Laws. plantations in California and Oregon where topsoil had been windrowed during site preparation, but that it was much less pronounced where topsoil had remained intact.

In South Australia, Keeves (1966) found that growth rates on some low site quality sandy soils supporting second-rotation stands of *Pinus radiata* D. Don were about 40-percent lower than in the first rotation following clearcutting and slash burning (Fig. 1). Squire and others (1985) traced this decline in site quality to increases in moisture and nutrient stresses in trees if the forest floor had been consumed during slash burning. Retaining logging slash reversed this effect and increased productivity in second rotations above that in first rotations. The cause of the decline seems centered on loss

¹ Presented at the 1989 National Silviculture Workshop, Petersburg, Alaska, July 10-13, 1989.

of organic matter, rather than burning *per se*. Wiedemann (1935), summarizing the effects of litter raking on growth of *P. sylvestris* L. on mesic sites in eastern Germany, found productivity was lowered nearly two site classes where litter had been routinely removed. Soil density also increased. This was confirmed recently in New Zealand's pumice region. Removing needle litter annually for 17 years reduced volume growth of *P. radiata* by 12 percent, and produced nutrient deficiencies in the foliage (Ballard and Will 1981).

Sands (1983), working with *P. radiata* in southern Australia, found sizable increases in soil compaction and strength on sites converted from pasture to first- and second-rotation pine plantations. Root growth essentially ceased at soil strengths of 3,000 kPa—penetrometer resistances that were found in some plantation soils. He concluded that maintenance of desirable physical soil properties depended strongly on the maintenance of soil organic matter. As a consequence of these and other studies, a soil classification system has been proposed recently for New Zealand that relates long-term productivity decline to nutrient loss and soil compaction (Hunter and others 1988).

In the United States, most direct evidence of productivity decline has been short-term or retrospective. Froehlich and others (1986) and Helms and others (1986) found that stem volumes of pines growing on compacted skid trails and landings were about one-fifth less than volumes of those growing on less-compacted soils nearby. However, retrospective studies such as these lack the precision needed to set accurate monitoring standards. Usually, initial soil conditions are unknown, and results may be partially confounded by differences in stocking, weed competition, and possible displacement of topsoil. For example, in their retrospective study of soil compaction in a 16-year-old *P. ponderosa* plantation, Helms and others (1986) found that height growth was correlated more closely with soil N availability than with current bulk density or any other variable. These findings illustrate two important points. First, "causal" factors are not easily identified in retrospective studies (nor can soil-monitoring standards be derived very well from unmeasured historic conditions). Second, physical and chemical impacts do not occur in isolation in operational forest practice. Operations producing compaction also may affect nutrient availability.

Most North American research on long-term impacts has centered on nutrient losses (particularly N) under varying harvest intensities, rotation lengths, and site preparation practices. Generally, about one-tenth of the total ecosystem N is in the standing forest (Alban and others 1978, Wells and Jorgensen 1979), with about half of this contained in the crown. The forest floor is another

important N component. Depending on climate, the N content of the forest floor may be one to three times that of the standing forest (McColl and Powers 1984). On the average, a 1-percent increase in biomass removal spells about a 3-percent increase in nutrient removal (Switzer and others 1981). Presumably, the shorter the rotation or the greater the degree of utilization, the greater the impact of nutrient removal. But reports of long-term trends largely are speculative and based on hypothetical models of varying complexity which are based on nutrient cycling. Aber and others 1978, using computer simulation of N cycling for northern hardwoods, concluded that yields might decline if rotation periods were less than 60 to 80 years.

All models are abstractions of reality and contain biases caused by our imperfect knowledge of natural processes. Were the impacts of forest practices merely nutritional, they could be corrected through fertilization. However, as Wells and Jorgensen (1979) have cautioned, physical properties of soil are affected by timber management practices as readily as nutrient properties, and potentially they are just as important to sustained productivity. Soil chemical and physical properties are influenced simultaneously by most—if not all—forest management field practices (McColl and Powers 1984). Accordingly, a sound program of research or soil monitoring must consider chemical and physical soil properties together.

The Law

The Multiple Use-Sustained Yield Act of 1960 (Sec. 4.[b]) binds the Forest Service to achieve, and maintain in perpetuity, outputs of various renewable resources without permanently degrading the productivity of the land (USDA Forest Service 1983). Following the passage of this Act, Section 6.(g)(3)(c) of the National Forest Management Act of 1976 (NFMA) charged the Secretary of Agriculture with ensuring research and continuous monitoring of each management system to the end that the permanent productivity of the land is not impaired (USDA Forest Service 1983). Precedents had appeared in the National Environmental Policy Act of 1969 and the Forest and Rangeland Renewable Resources Planning Act of 1974 (USDA Forest Service 1983).

The Code of Federal Regulations for Forest Planning that followed NFMA requires the Forest Service to monitor the effects of prescriptions, including "significant changes in land productivity" (Code of Federal Regulations 1985). Although NFMA refers to "land" productivity rather than "soil," productivity of the land within any management system is determined by soil, climate, physiography, biology, and time (Jenny 1980). Of these, the soil is one factor that can be modified swiftly and

profoundly by common management practices. Thus, the Forest Service recognizes the soil as the most effective indicator of the land's productive potential (USDA Forest Service 1987).

To comply with NFMA and subsequent regulations, the Chief of the Forest Service has charged each Region with developing soil quality monitoring standards for detecting significant changes in long-term productive potential. Forest Service Regions are developing threshold standards for identifying potential losses in productivity of 15 percent or greater (USDA Forest Service 1987). This standard was set because it was thought to be the lowest magnitude of change detectable, given current monitoring technology. In principle, such laws and regulations are laudable, and procedures have been established for soil-monitoring operations (Hazard and Geist 1984). However, monitoring regulations, standards, and guidelines rest on the premise that the correct variables are being monitored, and that the relationship of these variables to potential productivity is known.

Assessment

What are the important variables? Evidence points strongly to soil porosity and site organic matter as the main variables affected by management that are related to long-term productivity. These two variables influence site productivity through their link with more fundamental processes (Fig. 2).

Soil Porosity

Soil porosity is tied to fundamental site processes in the following ways. Losses in large (macro) soil pores at the soil surface reduce water infiltration and enhance runoff and erosion. Reduced infiltration increases soil matric potential, leading to plant moisture stress and nutrient stress because of declining nutrient transport in diffusion or mass flow of the soil solution. Surface erosion also degrades fertility because organically-bound nutrients tend to concentrate near the soil surface.

Loss of large pores below the soil surface reduces aeration and increases the physical resistance of the soil to root penetration. In turn, this retards the activity of such obligate aerobes as fungi and reduces the capacity of plant roots to exploit new soil volumes. Fungal hyphae and exudates contribute to the integrity of soil aggregates that contribute to soil structure. Losses of large pores may impair drainage, thereby inhibiting root respiration and nutrient uptake. In acid soils, waterlogging may increase the solubility of iron and manganese to toxic levels.

Site Organic Matter

Organic detritus from plants and animals has both a physical and chemical role in controlling site processes. The forest floor breaks raindrop impact and reduces the erosive force of water and wind. It also mulches and insulates the soil against heat flux and reduces evaporative losses during warm weather. Site organic matter also acts as a major reservoir for plant nutrients, and is the principal supplier of nutrients and energy for soil fauna—particularly macro and mesofauna that create large pores through their burrowing action and produce mucus that coats soil peds and promotes aggregate stability. Soil fauna also transport forest litter into the soil where, through varying degrees of transformation, humic materials provide a sponginess that promotes resistance to permanent deformation.

Partially decomposed soil organic matter also becomes an energy source for microorganisms that convert organically-bound nutrients to simple mineral forms available for plant uptake. Low molecular weight ligands from decomposition also chelate such metal cations as iron and aluminum and reduce their toxicity to plants. Humus—the resistant, dark, amorphous, final stage of decomposition—imparts the soil with very high cation exchange and moisture retention properties. Thus, fresh to final stages of organic matter all mediate the major processes affecting soil productivity and site quality.

Clearly, soil porosity and site organic matter are important variables that are affected readily by many forest practices during timber harvest and site preparation. But beyond conceptual models such as that in Figure 2, we lack a specific understanding of what a given change in porosity or organic matter means in terms of its long-term effect on site quality. With few exceptions, functional models are rare enough to be considered nonexistent. As Miller and Hazard (1987) point out, uncertainty and skepticism will persist until we establish and maintain studies that help us document and understand the long-term effects of forest practices on productivity.

Work is needed at both the fundamental and applied level to quantify the effects of soil disturbance on productivity—not only in a timber management sense, but in a more fundamental sense as well. We know little about the inherent carrying capacity of forest sites for producing vegetation. Yet, the capacity of a site for producing vegetation is a good index of its capacity to produce other resources useful to society. The processes affecting this carrying capacity can be understood only through deliberate manipulation of the site—an approach that is distinct from most ecosystem process research, which has centered on narrowly defined objectives in unmanipulated stands (McColl and Powers 1984). In my opinion,

traditional lines of inquiry promise modest returns, and a new research thrust is needed. The success of such a thrust depends on a continual feedback cycle of planning, experimentation, monitoring, and evaluation until objectives are accomplished (Miller and Hazard 1987).

A COOPERATIVE NATIONAL STUDY

Objectives

Research	Development
How does soil disturbance affect:	Facilitate soil monitoring efforts by:
Carbon allocation.	Calibrating changes in soil properties against (i) stand productivity; and (ii) total productivity.
Water use.	
Nutrient use.	Evaluating/developing practicable field monitoring methods.
Other processes.	Developing means for extending results to a broad array of sites.
Resistance to pests.	
Fundamental productivity.	

The study is designed to favor fundamental investigations into the joint role of soil porosity and site organic matter in their effect on site processes controlling productivity. Results also will validate soil quality standards and monitoring methods used by NFS, and new procedures will be developed as needed. The generic plan described below is condensed from Powers and others (1989), and serves as a template for more detailed plans developed by Steering Committees within each Forest Service Region.

Coordination

Three levels of coordination are described to ensure the achievement of national and regional objectives.

A cooperative effort is underway between Forest Service Research and National Forest Systems (NFS) with the objectives of (1) quantifying the effects of soil disturbance from management activities on soil productivity; (2) validating standards and techniques for soil quality monitoring; and (3) understanding the fundamental relationships between soil properties, long-term productivity, and forest management practices (Powers and others 1989). These objectives can be stated as complementary "Research" and "Development" topics.

National Coordination

National coordination and review will be provided by Timber Management Research, Forest Environment Research, Timber Management, and Watershed and Air Management Washington Office staffs. Coordinating activities will include:

1. Developing priorities and funding opportunities.
2. Reviewing Station/Region implementation plans.
3. Highlighting accomplishments.

National Technical and Regional Steering Committees will be responsible for establishing and conducting the studies.

National Technical Committee

The National Technical Committee will consist of Principal Investigators and Regional Soil Scientists who presently are involved or who plan to be involved soon in implementing and maintaining studies and interpreting study results. This Committee, chaired by a Principal Investigator appointed by the National Oversight Committee, will have five main responsibilities:

1. Review study proposals to ensure that scientific methods are consistent and appropriate to meet program objectives.
2. Establish a national data base of research results.
3. Inform the Washington Office of progress, needs, opportunities, and substantive findings.
4. Coordinate and prepare results for publication.
5. Review, evaluate, and incorporate modifications to the proposals.

Regional Steering Committee

The Regional Steering Committee consisting of the Experiment Station Principal Investigator, Regional Soil Scientist, and Regional Silviculturist will initiate and encourage cooperative and collaborative ties with National Forests, Ranger Districts, and other researchers. This committee will identify individual study sites, prepare specific study plans based upon this general plan, and implement the studies. This committee shares responsibility with National Forests and Ranger Districts for ensuring public awareness of the program. Departures from procedures described in this study plan must be approved by both the National Technical Committee and the National Oversight Committee. Study sites should be identified in the Monitoring Plan for each National Forest.

APPROACH

Treatments

Treatments involving full factorial combinations of soil compaction and organic matter removal will be applied to benchmark soils within the major commercial forest types of the United States. Beginning in 1989, the work will be piloted in Regions 5 and 8 on lands expected to be managed intensively in the decades ahead (Powers

1987), but all Regions and Stations are encouraged to participate.

Within each Region and forest type, stands near rotation age will be found that have stocking and forest floor characteristics expected of stands under management. Site quality at each candidate site must be uniform. Soils also must be uniform and typical of other soils in the Region. Candidate sites will be arrayed along a soil property gradient believed to be related to potential productivity (such as water holding capacity, drainage class, or rooting depth). Sites will be selected randomly for treatment from "low," "medium," and "high" positions along this gradient. Each site selected will be replicated at least three times geographically. Sites will be characterized before treatment according to procedures established by Powers and others (1989).

Nine treatment combinations of the following levels of organic matter removal and soil compaction will be assigned randomly to the core treatment plots.

Organic Matter Removal

- OM₀ Boles removed, only
- OM₁ Boles and crowns removed (whole-tree harvesting)
- OM₂ Boles, crowns, and forest floor removed (all above-ground biomass)

Soil Compaction

- C₀ No compaction
- C₁ Intermediate compaction (half-way between C₀ and C₂)
- C₂ Compaction to about 80 percent of the difference between hypothetical growth-limiting bulk density (Daddow and Warrington 1983) and bulk density existing before treatment at 10-20 cm.

Under operational conditions, soil compaction can vary with depth and amount of land surface affected, depending on soil texture, water and organic matter content, equipment weight, and load distribution on the soil. In this study, compaction will be confined to the surface layers and horizons because:

1. The majority of fine feeder roots are found in the surface horizons.
2. Root and other organic debris on the surface distribute applied loads more evenly in forest settings than in tilled agricultural fields.

Techniques for achieving compaction treatments are the prerogative of the Forest Service Principal Investigator. Plots will be compacted before clearfelling if necessary to reduce work in moving organic residue. Where the forest floor is to be retained, successive swaths may be carefully lifted or rolled aside and the soil compacted. This is desirable because compaction might be difficult if a thick forest floor is present, and compaction procedures might drive organic matter into the mineral soil (which could increase mineralization rates and partially confound the experiment). Materials then will be replaced with minimal disturbance. Another pass by the compaction machine under minimal load will reestablish the forest floor/soil surface interface.

Biomass will be removed soon after felling in a way, specified by the Principal Investigator, that minimizes soil disturbance. A possible treatment arrangement is shown in Figure 3. This cluster of nine treatment plots will be separated from adjacent stands by an outer buffer strip at least 20 m wide. Other treatments—such as ameliorative practices or conventional harvest and site preparation techniques—may be installed on adjacent areas at the prerogative of the Regional Steering Committee, provided that they do not confound or alter the core treatment design. Plots will be monumented at each corner with permanent posts and described according to Curtis (1983). A standard weather station will be installed at each site to monitor air temperature, relative humidity, radiation, and precipitation. These weather stations will be compatible with other stations installed throughout the Forest Service.

Generally, treatment plots will be planted at about 2.5 m by 2.5 m spacing (Fig. 4) with seedlings of the appropriate timber type and a mixture of the best available genetic stock (for example, half-sib families adapted to the site that have demonstrated superior growth). The aim is to favor superior growth without

narrowing genetic diversity. Multiple plantings may be required to ensure nearly complete initial survival. Where this is done, trees will be thinned to the most vigorous seedling per spot by the third year. Natural regeneration (seeding or coppice) may be substituted where it is the usual method of regeneration. Each treatment plot will be split in half, creating two subplots of about 340 trees each (Fig. 4), with a measurement plot established from the fourth row of trees inward in each subplot.

After establishment, one subplot will be kept weed-free, using herbicides or manual control as needed. In the other subplot, regional vegetation will be encouraged to grow with the trees—the aim being to promote complete vegetative recovery as rapidly as site conditions permit so that the site approaches full carrying capacity. Regional vegetation may have to be reseeded or planted to subplots if there is reason to believe that revegetation will be poor. This split-plot arrangement creates a means for side-by-side comparisons of (1) stand productivity vs. total vegetative productivity; and (2) the effect of competing vegetation on tree growth. This core set of nine treatments can be supplemented with adjacent plots to examine treatments of regional interest, such as broadcast burning, windrowing, soil amelioration, partial cutting, etc. Such treatment plots should be characterized and monitored similarly to those in the core set of nine treatments.

Measurements

Study sites will be classified according to an integrated ecological classification system in Regions in which such systems are commonly used. A core set of measurements, detailed by Powers and others (1989) and outlined below, must be taken at each installation, both pre- and post-harvest, in order to ensure comparability among sites.

Pre- and post-treatment measurements
dealing with--

Post-planting measurements
dealing with--

Organic matter	Porosity	Productivity
Mass by component	Bulk density	Stocking
Logging slash	Soil strength	Height
Forest floor	Infiltration	Diameter
Mineral soil	Moisture release	Damage
Nutrients by component	Saturated hydraulic conductivity	Above-ground biomass in:
Logging slash		Trees (by component)
Forest floor		Other vegetation (by component)
Mineral soil		Species diversity

These core measurements are the responsibility of the Principal Investigator, and are not meant to preclude other measurements. Specific mensurational and analytic techniques must be reviewed and approved by the National Technical Committee. Breast-height diameters will be recorded for all trees in measurement subplots, and other measurements (height, volume, mass) will be recorded for a representative sample. The following minimum measurements are required in order to address most of the objectives listed previously.

Soil data

1. Soil profiles will be described in each measurement plot to the degree needed to define the soil unit, and forest floor and soil core sampling will occur at random positions. Pretreatment samples may be composited to reduce analytic costs and to produce a standard error of the mean of ± 10 percent, or as near to that as is practicable within budget constraints.
2. Infiltration rates will be determined centrally in each plot before treatment. Following treatment, rates will be determined at random multiple positions.
3. Intact soil cores will be taken near the same positions as the infiltration measurements for physical analysis of the 0-10, 10-20, and 20-30 cm depth classes. Measurements will include bulk density, saturated hydraulic conductivity, and moisture release. Soil strength also will be measured by penetrometer.
4. Soil samples will be collected near each intact core sampling position for chemical analysis including pH, organic matter, exchangeable cations, ex-

tractable phosphorus, and total nitrogen and sulfur using standard procedures. Samples may be composited to produce a minimum of three separate samples from each plot.

5. Principal Investigators are encouraged to examine other variables and techniques of scientific value, such as soil loss, root dynamics, nitrogen mineralization, or expressions of organic matter quality. New leads should be shared rapidly with other members of the National Technical Committee.

Vegetation data

1. Sites will be classified before treatment according to the classification system used by each individual Region (potential natural vegetation, habitat type, plant association, etc.).
2. Vegetation existing before harvest will be surveyed and listed by species, and changes will be monitored over time. At a minimum, the following attributes will be recorded:
 - Canopy cover
 - Canopy height
 - Biomass production of current growth
3. Survival, height, diameter, and crown length of planted trees will be measured at the first, third, and fifth year after planting, and at 5-year intervals thereafter. Height and percent cover of other regional vegetation, by species, will be measured at the same intervals.
4. Cumulative standing biomass and leaf surface areas will be estimated at 5-year intervals for all

vegetation by species through periodic biomass harvesting in the second row of buffer trees until the first thinning. Thereafter, trees removed in thinning will be used, provided that they are representative of remaining trees. Data from destructive sampling will be used in regression to estimate biomass from non-destructive tree measurements.

5. Plant damage will be recorded at each measurement interval using standardized tree classification codes (Curtis 1983).
6. Dry weight and nutrient content of current and year-old, upper-crown foliage of trees and perennial understory vegetation will be measured. Collections will be made at 5-year intervals, and timed to periods of greatest potential stress, such as near the completion of height growth (Powers 1984).

Silvicultural Tending

Trees will be protected from damage by mammals during the establishment stage using appropriate procedures, such as fencing, Vexar tubing, or both. "Trees-Only" subplots will be kept weed-free throughout the rotation using appropriate herbicides or manual procedures. A thinning schedule will be developed for each site according to the growth characteristics of trees in each treatment, and procedures will be determined by the Regional Steering Committees. Records will be kept of volumes, biomass, and nutrient content removed at each thinning so as to develop a complete record of gross productivity.

Responsibilities and Implementation

Costs, estimated at about \$74 thousand per installation for the first five years, will be shared by NFS and Research. In general, NFS is responsible for establishing and maintaining the sites. Research is responsible for data collection, analysis, and publication. Study plans prepared jointly by Stations and Regions will detail the responsibilities. Contacts and field visits with research and practicing entomologists, pathologists, and wildlife specialists should be frequent. Once funded, approximately 14 months will be needed to locate and install a series of study sites within a timber type. The first strong indication of long-term treatment effects can be expected in 5 to 10 years after planting on average sites (Fig. 5).

SUMMARY

Our ability to maintain a site's productive capacity faces increasing challenge through public review of Forest Land Management Plans and timber sales. In response to NFMA, Forest Service Regions are developing threshold soil quality standards for detecting declines in potential soil productivity. Such standards are based on best available information. Often, this amounts to professional judgment because research has not addressed the problem. Professional judgments will be subject to repeated challenge from many sectors. Results from this cooperative study will provide credible responses to many of these challenges, and will address related research needs across the nation.

This network of study sites will provide the scientific basis for validating soil quality standards established by NFS and will create a research opportunity of unusual scope and significance. Initially, existing standards for monitoring soil quality will be compared with interim findings and can be adjusted to reflect the most recent research results. With time, more substantive results will be available for future planning. All Regions and Stations are encouraged to participate to ensure the success of this joint program.

The experimental design provides researchers with the framework for comparing stand production with more fundamental measures of productivity. The conceptual model in Figure 2 suggests many research opportunities, including studies of water use efficiency, root dynamics, soil faunal dynamics, nitrogen mineralization, nutrient uptake and return, carbon partitioning into growth vs. defense compounds, and host-pest interactions. Because a gamut of stress conditions is imposed deliberately on vegetation, pest and disease interactions are likely, and multidisciplinary collaboration will be encouraged. Basic models of soil and growth processes can be integrated with site and climatic data to extrapolate findings to a broad array of sites, and to project the possible impacts of changing climate on future productivity. The work fosters close cooperation between Research and NFS, and opens doors for important work with university scientists.

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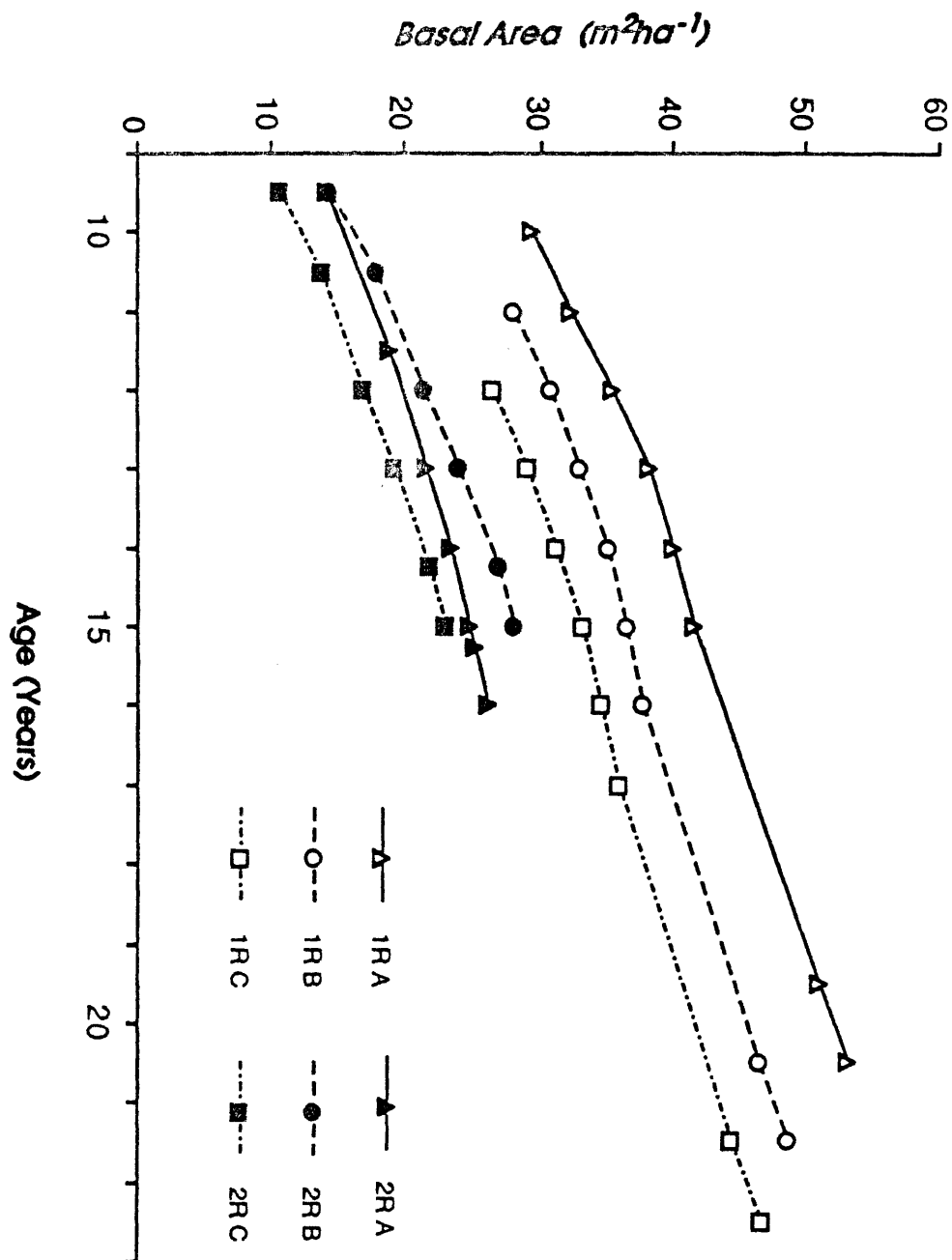


Figure 1.—Trends in basal area accumulation between first (1R) and second (2R) rotations of *Pinus radiata* for three plantation sites (A, B, and C) in the Penola Forest Reserve, South Australia. Common line weights indicate identical sites. From Keeves (1966).

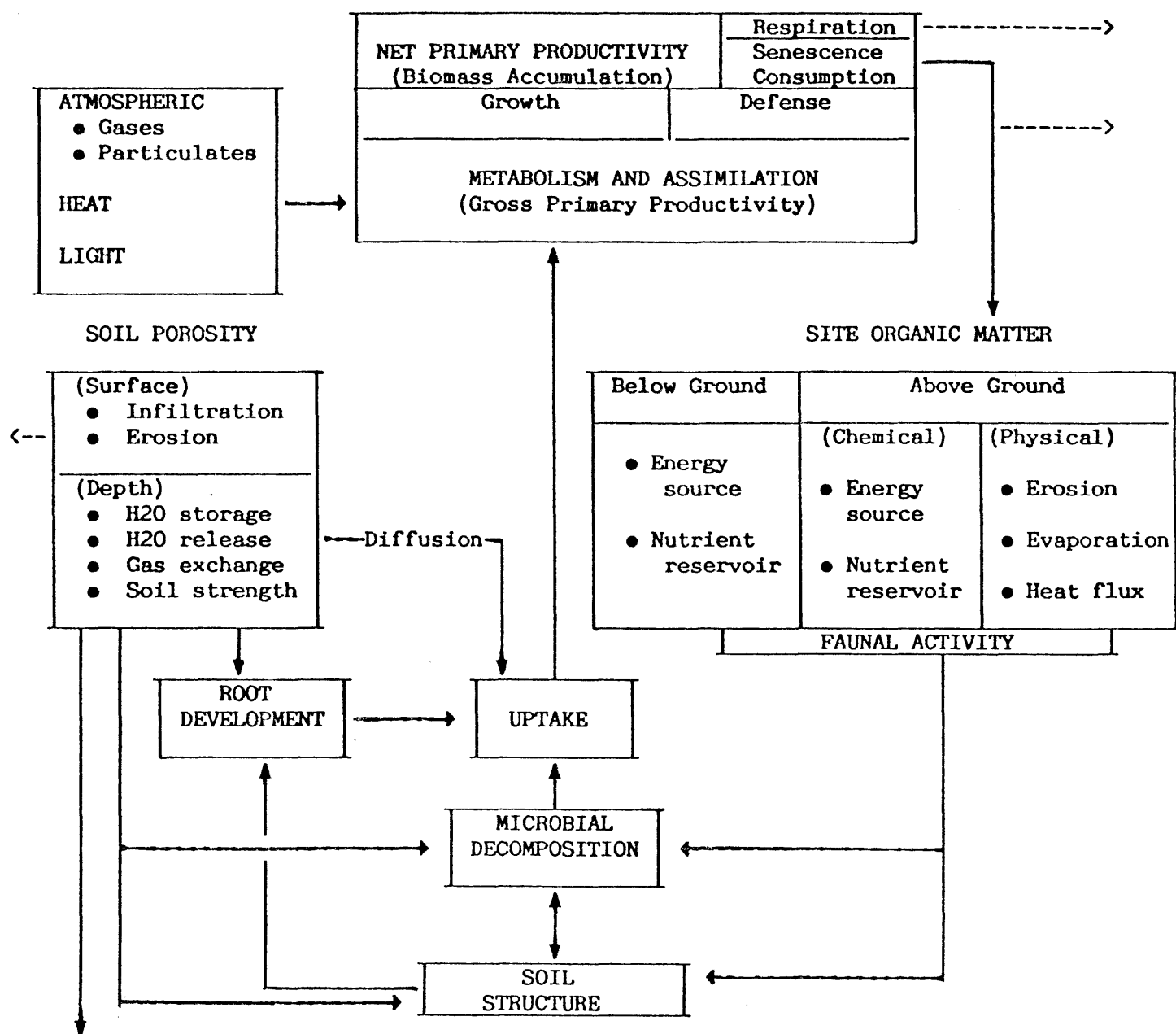
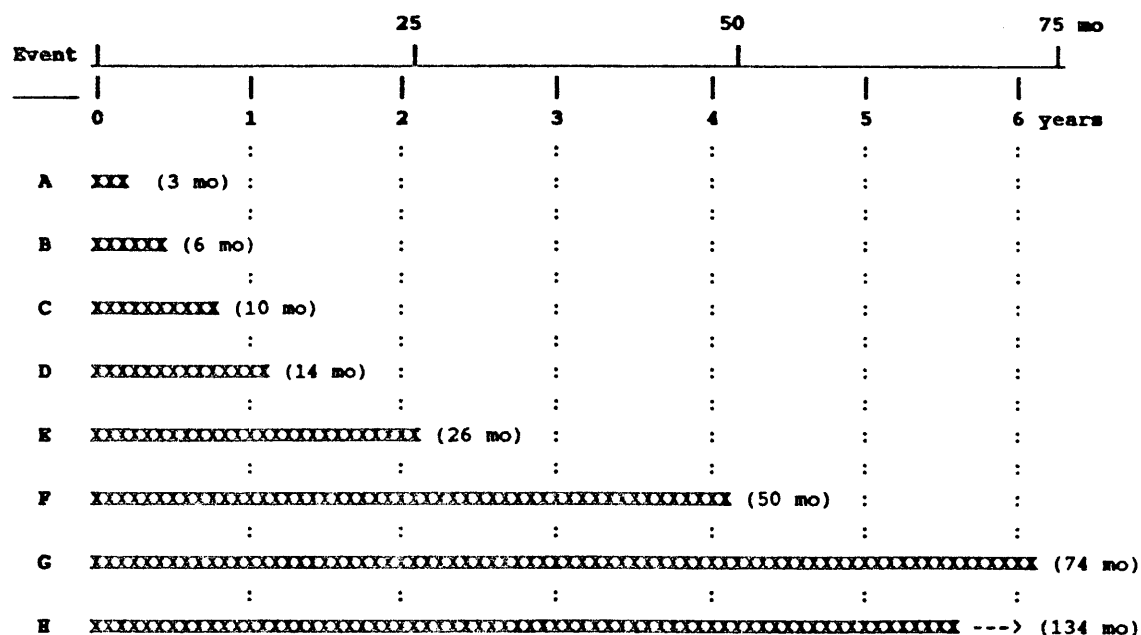


Figure 2.—Conceptual model of the role of soil porosity and site organic matter in mediating site processes that control net primary productivity.

		ORGANIC MATTER REMOVAL		
		OM ₀	OM ₁	OM ₂
C O M P A C T I O N	C ₀	(1) OM ₀ C ₀	(2) OM ₁ C ₀	(3) OM ₂ C ₀
	C ₁	(4) OM ₀ C ₁	(5) OM ₁ C ₁	(6) OM ₂ C ₁
	C ₂	(7) OM ₀ C ₂	(8) OM ₁ C ₂	(9) OM ₂ C ₂

Figure 3.—Generalized field layout of a 3 x 3 factorial arrangement of organic matter removal and compaction treatments. Plots probably would not be contiguous under field conditions. Other treatments or operational trials would be located nearby at the discretion of the Regional Steering Committee.



Event Codes:

- A: Develop regional study plan with approval.
- B: Identify candidate study sites.
- C: Select study sites, preliminary sampling, develop contracts and special provisions.
- D: Harvest, install treatments, plant, collect initial measurements.
- E: First main post-treatment measurements.
- F: Second main post-treatment measurements.
- G: Third main post-treatment measurements. First biomass measurements.
- H: Fourth main post-treatment measurements. Second biomass measurements.
(Probably the first valid indication of long-term productivity trends).

Figure 5.—Sequence and timeline for locating, installing, and measuring study plots. Plots would be thinned according to best management practices and the stand characteristics of that treatment. Sampling would continue throughout the rotation.

TURBOCHARGING YOUR SILVICULTURAL PRESCRIPTIONS (Or ANYTHING ELSE on a computer)

By Dave Ellen
Mt. Hood National Forest
2995 NW Division St NW
Gresham, OR 97030¹
(503) 666-0700 X127

ABSTRACT

The increasing pressure of appeals and legal challenges means silvicultural prescriptions must be better than ever because they may have to stand up in court. Delayed projects are often implemented long after the author has moved away, leaving proper execution completely dependent on the quality and completeness of the silvicultural prescription.

Turbocharging makes the task of prescription writing less onerous by putting to full use the short-cut power of the CEO USER COMMAND. Known as USER COMMAND in the Data General CEO environment, similar power resides in almost all professional word-processing software: DEFCMD (CEOWrite), SIORTHAND MACRO (Wordstar), COMMAND MACRO (WordPerfect) and so forth. USER COMMANDS are custom-designed to structure prescription outlines, insert repetitive text, format complicated tables, or perform any writing task that is needed more than once.

The recommended concept makes preparation of silvicultural prescriptions faster, easier, more consistent, more complete, better looking and completely responsive to the needs of the silviculturist and the stand.

INTRODUCTION

I'm not here to sell you a used car. . . You already have a Mercedes, but the turbocharger that came with it is rolling around in the trunk. I want you to take it out and bolt it on.

It won't cost you a cent, but I guarantee it will make your work go faster.

. . . If you're willing to make an investment in personal productivity using your Data General or personal computer . . .

Do not tell me complete silvicultural prescriptions take too much time. I spent six weeks in 1988 going through more than 280 administrative appeals of buy-back timber sales. One of the charges made on almost all of them was that "silvicultural prescriptions are outdated and inadequate." I looked at every one of those prescriptions. Few started from a set of silvicultural objectives, and most of them would be indefensible in a silvicultural tribunal.

Face it now or face it later: your silvicultural prescriptions are going to be in court, if not by themselves at least as part of a timber sale appeal package. If your prescriptions are "outdated and inadequate," as charged, the appeal gains credibility at the expense of your professional pride. If you move on before your prescriptions are implemented, your legacy may haunt you.

We have to do better, but as Wendall Jones (Director of Timber Management, Pacific Northwest Region) has said many times, "we gotta do it better **FASTER**."

The **turbocharging** method lets you do it better **FASTER**, easier, more complete and more fun. You can go out in the woods more often and stay longer. Your prescriptions will benefit from your increased field knowledge.

My personal files contain a letter from the Helicopter Loggers Association. Most of the letter deals with timber sale issues, but there's a little gem at the end:

" . . . Finally, one thing that really impressed us was the amount of time your silviculturist had obviously spent 'on the ground' in this planning area. He should be commended for this as it's not necessarily a normal procedure in the Region from our experience."

I'm proud of that letter, because it came from folks who look at only the roughest kind of ground. Does the computer chain you to your desk? Not if you use the turbocharger.

Here's how to bolt on your **TURBOCHARGER**:

¹ Presented at the 1989 National Silviculture Workshop, Petersburg, Alaska, July 10-13, 1989.

Imagine that you are going to build a log cabin in Petersburg, Alaska, number the logs, tear it apart, ship it to Skagway and reassemble it there. Imagine that once you cut and notched all the logs, they would magically replicate themselves and you could assemble that cabin in any shape you wanted, as many times as you wanted – in Ketchikan, in Juneau, in Missoula, Albuquerque, Fort Collins, Asheville, or any other place of your choice. Turbocharging your silvicultural prescriptions is like that. With the computer, you reassemble parts of a silvicultural prescription in any order you want, as many times as you want, and then remodel it to suit your site specific needs.

Almost everyone here has access to a Data General computer. I've patterned my examples for that hardware, but the concept—the heart of what I'm saying—is valid for any computer with professional word-processing software.

Of more than a hundred keys on the Data General keyboard, you need only three to turbocharge your silvicultural prescriptions.

SHIFT-F1 is the HELP key. You can learn everything there is to know about the Data General using this combination of two keys. If you get stuck, these are the keys to press.

But this is not a lesson on how to use the HELP function. If you want that, just press those two keys and you'll get it. If you don't have a Data General computer, you'll find that almost all word-processing software has a similar HELP function, though procedures and terminology may be slightly different.

F2 is the COMMAND key. This is the one with the power to turbocharge your silvicultural prescriptions. If you're using a Personal Computer with some other word-processing software, the keys may be different, but the concept is the same.

The COMMAND key is used to summon the building blocks of your silvicultural prescriptions, just like you would the logs of your magical log cabin. When you issue a COMMAND, all the steps you would have to type in by hand are done automatically. You can use the COMMAND to read in the structure of a complicated table, complete with the correct tab stops. You can use it to read in a set of silvicultural objectives that you use over and over again. You can use the COMMAND to read in an outline, or a portion of an outline. You can use it to locate the cursor at the correct position for input. You can use it to delete everything and start over.

In short, the COMMAND function is limited only by your own imagination. If you can do it on a computer, you can do it over and over again faster with the COMMAND function.

If you're getting the idea to run off "canned" or "boiler plate" prescriptions, you're talking about a misuse of this technology. Like any tool, turbocharging can be misused – but do it at your peril. I want you to think of this as a method for structuring NEW prescriptions so they are both complete and follow a recognizable format – a format that is flexible to meet YOUR needs.

To get started, take a look at your best silvicultural prescriptions. If you find that your day to day prescriptions are none too good, go back to the one you prepared for Certification, or borrow a good one. Look at several different prescriptions – say one for precommercial thinning, one for commercial thinning, one for regeneration cutting and one for fertilization.

Lay them all out together, and compare their content and structure. See what elements they have in common. For example, you might look for:

1. A cover sheet with space for a map and legal description, possibly with a space for notations and penned-in updates.
2. A summary of the prescribed treatment. Bare bones.
3. A set of silvicultural and land use objectives. (You'd be surprised at how often this is neglected in "every day" prescriptions.)
4. A description of the abiotic and biotic environments.
5. A complete description of the stand, perhaps a stand exam summary.
6. A set of silvicultural options: Things you could consider prescribing.
7. Your selected option, and the reasons you selected it.
8. Operational Instructions. Specific and in detail, as needed.
9. A list of recommended contract clauses, and specific terminology for them if needed.
10. Recommendations for other functional specialists.

11. An assessment of significant and cumulative effects of the prescription.

12. An activity schedule and monitoring plan.

13. A list of supporting literature references.

I could go on, but you get the idea.

The point is, all prescriptions have certain characteristics in common, but good ones must be site-specific.

You make the computer do the things they have in common, and YOU do the site specific things. The computer will give you time to do it.

Look again at your prescriptions, and decide what purpose you want them to serve and how you want them to look. Reduce them all to an outline. Some will have a slightly different outline than others, or have different combinations of text, such as your sets of silvicultural objectives.

That's OK. Here's where the computer gives you extra power.

Break the outlines into manageable segments. Save each of the segments as a document file in the CEO environment, or on a diskette for your personal computer. Give the segments each a file name that will remind you of its function. (For example, I call my cover sheet "MAP" because it has a space to place a map of the project.)

Now look at the text of your prescriptions. Pick out parts that you find yourself typing over and over again, or that you wish you could include, but don't think you have time for. (For example, you could prepare marking guides that are appropriate in different stand types. Here's one example I often use for leave tree marking in a shelterwood cut. I named this building block **MHSH** to remind me that a set of Marking guides for use in a **H**arvest **S**helterwood cut:)

BEGINNING OF EXAMPLE MHSH

H. INSTRUCTIONS FOR MARKING CREWS

[presale specialists]:

1. Method: Mark LEAVE trees.

2. Species preference in descending order: *
Insert list *

3. Disease: Do not mark trees that have butt rot, cankers, spike tops, broken tops, fungus fruiting

bodies (conks), mistletoe, brown or extremely thin foliage, or other indications of disease.

4. Form: Select LEAVE trees that have a cylindrical bole for (slight taper), straight bole, and limbs that are small and tend to prune off naturally. Trees that are crooked, highly tapered or have persistent limbs or large knots should be avoided where possible. These characteristics are **highly heritable**, so the quality of offspring from seed cast by these trees is likely to be similar.

5. Windfirmness: Do NOT mark trees that show signs of being uprooted. Look for a ring of soil cracking around the base.

6. Diameter: Mark trees that are * inches dbh or larger if possible.

7. Crown ratio: 20 to 40 percent (do not mark trees with limbs near the ground or that have less than percent crown ratio.)

8. Select good seed-producing trees. Trees with many cones on them or in the duff layer beneath are likely to be good seed producers.

9. Marking density: Use the attached table to determine spacing and basal area ranges that will yield the proper amount of shade or protection for the seedling regeneration.

Important Note! The function of a shelterwood is to provide seed, protection, and shade. Trees with full crowns provide the best and most efficient protection and shade. The spacing and basal area table should be used to check marking after leave trees have been selected on the basis of their crown characteristics. It is not intended to be an inflexible rule, and should be used as a tool to avoid under-marking and over-marking.

Save the blocks of text you plan to use repetitively, each with its own document or file name that reminds you of its function.

Now you have the basic building blocks for any silvicultural prescription you can write. They're building blocks. Call them that. If you use them like "canned meat" or "boiler plate," you're abusing the tool and you're not enjoying its full power.

NOTHING IN THIS METHOD RELIEVES YOU OF THE NEED FOR VISITING THE FIELD AND DOING THE LEGWORK!!!

But it does free you up to spend more time in the field.

First use the outline elements of your set of building blocks to construct a sheet for taking notes IN THE FIELD. You won't need much text for this field sheet, but leave a lot of white space for taking notes. Make a bunch of photo-copies of your field sheets and head for the field.

You have your own field methods for collecting data and ground level knowledge, and you should tailor your **turbocharged** field notes around this most important part of the job.

Now let's assume that you have been to the field, and have your completed notes taken on the same outline you plan to use for your prescription.

Turbocharging comes into play when you are ready to assemble the building blocks into finished prescriptions.

Sit down at your DG terminal or personal computer. Open up a blank document.

Now press those two help keys again: SHFT-F1. The computer will ask whether you want to see the electronic manual. Say **YES**. The computer will ask you what topic you are interested in. Type in **USER COMMANDS**. In a moment you will be introduced to a complete lesson on how to create **USER COMMANDS**. I'm not going to go into it, because the computer can do a much better job of teaching you.

Follow the instructions in the electronic manual to create **USER COMMANDS** that will read in the building blocks of your turbocharged silvicultural prescriptions.

Once you have created a **USER COMMAND**, all you have to do to activate the **COMMAND** is press function key **F2**, **COMMAND** and type in the name of the command you want. The computer will retrace all the steps you mapped out for it, and place the building block in the proper place in your prescription.

That's all there is to it. Create one **USER COMMAND** for every task you think will be used repeatedly. You can have 99 **COMMANDS** on the Data General, and an almost unlimited number on a personal computer.

Turbocharging your silvicultural prescriptions takes a bit of effort to get rolling, but once you have the basic idea, it's a snap. You can use these same ideas to speed

up all your writing. Schedule up your summer for the field. Do the ground pounding, and come back with a good set of notes.

USER COMMANDS will build up the structure of your prescriptions and fill in text that is common to all of your prescriptions.

Once the **turbocharging** is done, you treat the prescription like any other document. Make changes in it, add field observations, add stand exam data if needed, delete everything you don't need. Dress it up if you need to and print it out. It's done!

Turbocharging your silvicultural prescriptions does not require new technology, and it does **NOT** do any decision-making for you. It is **NOT artificial intelligence** nor is it an **expert system**. **YOU** provide **real** intelligence and expertise, and the ground pounding.

IN SUMMARY:

Decide how you want all your prescriptions to look. Build up the basic structure like you would a log cabin, then break it into segments as if you were going to number the logs and rebuild the cabin over and over again, by the numbers, in different configurations.

Teach the computer once to follow the sequence of keystrokes you need to assemble each part of the prescription. It will never forget, once you have given it the correct instructions.

If you are willing to make this investment in personal productivity, you'll be out in the field more and enjoying your work more.

And your prescriptions will take on a professional quality you've never been able to give them before.

I challenge you to try it.

I'll be glad to help you. I can arrange to send you a complete system for the Data General or personal computer with CEOWRITE software, but I encourage you to start from scratch so your prescriptions are truly yours.

At least for a while, you can reach me at the Mt. Hood National Forest.

EXAMPLE 1:

Practice example with CEO on the Data General computer:

Set up a **FUNCTION KEY** to search for an asterisk. You can use this to quickly move around your outline to predefined points marked by an asterisk. This saves many keystrokes when you are ready to put in data.

1. Press **F2** (**COMMAND**), type **USER**
2. Choose 1, **CREATE**
3. type in **F10** (or any unused function key)
4. type in **Searches for an asterisk ***
5. Choose 1, **ACTIVITY WHERE INVOKED**.
6. Press **ESC** to initiate the sequence following.
7. Press **SHIFT-F6**, **FIND**, type in ***** (an asterisk)
8. Press **F1**, **EXECUTE**
9. Press **ESC** to complete the command
10. Press **F1**, **EXECUTE** to activate the command
11. Press **CANCEL/EXIT** to return to the working environment

You can now press **CTRL-SHIFT-F10** to search for an asterisk automatically. In the following examples, notice asterisks (*) positioned at the data entry points.

Follow similar steps to create additional commands.

PRACTICE EXAMPLE 2:

```
:_____ :
:Table for ABIOTIC ENVIRONMENT :
:Press F2 (COMMAND) type HABIO :
:Press F1 (EXECUTE)-----> :
:_____ :
```

HINT: Give your reminders a **USER NOTE** text attribute. You can then suppress printing so they do not appear in the document.

I. ABIOTIC ENVIRONMENT:

A. TOPOGRAPHY:

UNIT OR AREA SLOPE ASPECT ELEVATION SOILS (SRI UNIT)

* * * * *

HINT: Design the command **HABIO** to include a step that searches for the first * (asterisk). Then use the **FUNCTION KEY** you created in example 1 to search for the remaining data entry points marked by an * (asterisk).

Soil Resource Inventory (SRI) Management Implications:

*

B. CLIMATE AND MICROCLIMATE:

*

A silvicultural prescription is less a set of instructions than a confession of faith in the future: of the tree, of the stand, of the forest, of mankind, and of the earth. It is the planting of a farmer whose crop will outlive him. It is a prayer for non-believers.

DETERMINING THE FEASIBILITY OF GROWING SEEDLINGS IN THE PACIFIC NORTHWEST FOR PLANTING ON FOREST SITES IN SOUTHEAST ALASKA

John Zasada and Peyton W. Owston
USDA Forest Service
Pacific Northwest Research Station
Forestry Sciences Laboratory
Corvallis, Oregon 97331

Dennis Murphy
USDA Forest Service
Timber Management Staff
Washington, D.C.¹

ABSTRACT

This study compared the performance of Sitka spruce and western redcedar seedlings grown at the USDA Forest Service nursery in Petersburg, Alaska, with those grown in Idaho (planted in 1986) and Oregon and Washington (planted in 1987). Based on survival and growth after two and three growing seasons in the field, it appears that seedlings of the proper seed sources grown in the Pacific Northwest can be used to meet silvicultural objectives in Southeast Alaska.

INTRODUCTION

The Tongass National Forest has, in the past, relied almost exclusively on natural regeneration to restock harvested areas. Although this is successful in almost all cases, situations arise where planting may achieve objectives that are not possible with natural regeneration. These objectives include improving stocking and distribution of selected species; rapid restocking of difficult to regenerate sites (e.g., river terraces) or sites prepared by prescribed burning of slash; and to introduce genetically improved materials. Furthermore, trials in the past have shown that planted seedlings can develop rapidly on some sites; thus, artificial regeneration may permit reduced rotation length on sites where intensive management is prescribed.

Production of high-quality nursery stock is the first step in a successful planting program. Seedlings with high-growth potential are essential to achieving any advantage over natural regeneration. The primary source of seedlings in Southeast Alaska has been the USDA Forest Service's B. Frank Heintzelman nursery in Petersburg, Alaska. Because of relatively low demand for seedlings, however, it is not possible to achieve the economies of scale found in large nurseries that can spread their fixed

costs over many more units of production. Because of the high cost of seedling production in Petersburg, the question was asked: Would it be cost effective to grow trees in the large forest tree nurseries of the Pacific Northwest for outplanting in Southeast Alaska?

For this to be successful, seedlings grown outside of Alaska must have potential for survival and growth that is equal to or better than that of Alaskan-grown seedlings. To address this question, a cooperative study involving Region 10 and the Pacific Northwest Research Station (PNW) of the USDA Forest Service was begun in 1986. The Reforestation Systems research unit of the PNW has responsibility for conducting the study and preparing reports. This report briefly describes the study and results to date.

OBJECTIVES

The primary objective of the study was to compare the performance of seedlings grown at the Petersburg nursery with those produced at the Forest Service nursery at Coeur d'Alene, Idaho, (outplanted in 1986) and at the Silvaseed Company nursery in Roy, Washington (outplanted in 1987). Secondary objectives that could be examined as a result of the study design were to compare performance of (1) different seed sources; (2) different stocktypes of seedlings; (3) seedlings on burned and unburned sites; (4) spring and fall planted seedlings; (5) natural regeneration with that of the planted trees.

METHODS

Sitka spruce seedlings were outplanted in 1986 and 1987; western redcedar was planted in 1987. Seedlings were grown at Petersburg and Coeur d'Alene in 1985

¹ Presented at the 1989 National Silviculture Workshop, Petersburg, Alaska, July 10-13, 1989.

and at Petersburg, Silvaseed Company, and the PNW Forestry Sciences Laboratory in Corvallis, Oregon, in 1986. Seed sources from Alaska were used and were selected for the seed zones in which the study sites were located. Trees were planted on the Ketchikan, Thorne Bay, Wrangell, and Hoonah Ranger Districts. Seedlings were planted in rows of 25 or 30 trees that were marked with individually numbered tags. Tree heights were measured immediately after planting and in the fall of each year; diameters were measured on about one-third of the trees. The condition (e.g., animal damage, frost damage, needle color, presence of competition) of each tree was noted at the time of annual measurement. Natural regeneration was surveyed on one-third of the planting spots at the end of the third year of the study.

Most of the seedlings were grown in styroblock containers (4 cubic inches per cavity). Trees grown at the Coeur d'Alene nursery were in individual plastic tubes (4 cubic inches each). Trees were grown in both types of containers at the Corvallis research greenhouse. In addition, some Sitka spruce seedlings initially grown in containers at Coeur d'Alene were transplanted at the Silvaseed Company and planted as plug + 1 bareroot stock.

RESULTS

All of the seedlots produced seedlings that were healthy and possessed good color and vigor. Average seedling sizes generally fell below accepted targets for stem diameter. The roots of some had low dry weights, and the height growth was frequently excessive—especially in Petersburg. The size characteristics followed expected growth patterns considering the latitude of the sources and the growing schedules employed—they do not reflect poor nursery practices. The results, however, do suggest some ways in which seedling sizes and weights can be improved in the nurseries.

On the average, seedlings grown in Petersburg were initially taller than those grown in the Pacific Northwest. These differences were most pronounced between the Petersburg and Coeur d'Alene Sitka spruce planted in 1986 and redcedar planted in 1987. Seedling diameters were similar between nurseries. Of 27 individual seedlots of 1-year-old container seedlings of both species at four different locations, those grown at Petersburg met the general "industry standard" of 0.5 grams of dry root mass per seedling in one of eight lots; Coeur d'Alene results were zero out of three; Silvaseed was three out of six; and Corvallis was six out of ten. Shoot/root and height/diameter ratios were higher for both species grown at Petersburg than at any of the Pacific Northwest nurseries. The plug + 1 Sitka spruce, as expected, had

much more mass than the container trees. They also had lower height/diameter and shoot/root ratios.

We anticipated and found high survival rates and good growth due to the relatively moist and mild environment of Southeast Alaska—with a few exceptions that were related to special site conditions and are noted below.

Performance of the trees planted in 1986 varied considerably between sites after three growing seasons. Average survival was slightly higher for the trees grown at Petersburg. Severe animal damage reduced survival on one site, and frost damage seriously affected survival on another. Seedlings from Coeur d'Alene were damaged more than those grown in Petersburg. Total height of seedlings from the two nurseries was similar after 3 years, and third-year increment was the same or greater for Coeur d'Alene trees compared to Petersburg trees. The greater damage to Coeur d'Alene stock was probably due to it having been grown as part of a late-season crop rather than due to the location of the nursery.

For Sitka spruce and western redcedar seedlings planted in 1987, survival averaged generally greater than 80 percent for both species and the three nurseries two seasons after planting. At all but one of the sites, average seedling height at time of planting was significantly greater for the trees from the Petersburg nursery. However, after the second growing season, these differences had disappeared. Second-year height increment was the same or better for Silvaseed trees as compared to Petersburg trees.

Concerning some of the secondary objectives: (1) there were significant differences in performance among seed sources on some sites; (2) at one site, trees planted in fall are performing as well as trees planted in spring; (3) plug + 1 seedlings show promise as an alternative stocktype in Southeast Alaska.

CONCLUSIONS

Two or 3 years of performance after planting is too short a time to accurately predict long-term performance. However, the results to date do suggest the following:

1. Planted seedlings do initially survive and grow well in Southeast Alaska. We believe, however, that it would be useful to continue tracking these seedlings to see if they ultimately become part of the next crop or are suppressed by vigorous natural regeneration.

2. Performance of seedlings grown in Alaska and the Pacific Northwest does not differ significantly in survival or height after 2 or 3 years in the field, and relative growth rates are higher for the latter. This indi-

cates that seedlings produced in the Pacific Northwest can be used to meet silvicultural objectives in Southeast Alaska. However, certain nursery specifications are required: The Northwest nursery must be able to extend photoperiods, the seedlings should be grown for a full and normal growing season, and they should be grown in styroblocks at no more than 80 seedlings per square foot density.

3. One indication that caution needs to be exercised in producing trees for Alaska in the Pacific Northwest was the greater animal and frost damage to trees grown at the Coeur d'Alene nursery and planted in 1986. However, those seedlings were produced in a late-sown crop and were shipped prior to completion of a conditioning phase. Thus, they were probably more succulent and less cold hardy than those produced in synchronization with the normal growing season or those allowed to complete the full late-crop schedule.

4. Perennial plants generally have indeterminate height-growth habits in their first year. Those from relatively mild climates have this characteristic in strong measure, and it is exacerbated by long photoperiods. This undoubtedly is the cause of excessive height growth and marginal root and diameter growth of many of the

seedlings—top growth hinders root growth, because the actively growing tops can utilize photosynthate before it gets to the lower stem and roots. We have no doubt that nursery procedures can be improved in both locales to counteract this growth tendency. We doubt, however, that procedures for the Petersburg nursery can be improved to the point that the stock grown there would dramatically outperform stock from the Pacific Northwest.

5. There could be shipping problems with producing stock for Alaska in the Pacific Northwest that could reduce its performance when they occur. The best way to reduce these periodic occurrences would be to have cold storage facilities at the receiving site or sites in Alaska.

6. Plug + 1 bareroot seedlings are a promising stocktype for Southeast Alaska.

7. Good performance of trees planted in the fall at Salt Lake Bay suggests that the time of planting needs to be examined as a means of improving seedling performance.

CHALLENGE, OPPORTUNITY, AND OBLIGATION

Dr. William R. Wood
President (Emeritus)
University of Alaska¹

"WHERE HAS SUMMER GONE?

AND SPRING SO FAR BEFORE?

LOVELIEST OF TREES, THE SILVER BIRCH

SHAKES ITS CROWN OF GOLD;

WINE-RED, THE LOW BUSH BERRIES TEASE;

'TOMORROW,' THEY SAY,

'IS TIME ENOUGH FOR SNOW

... AND MEMORIES.'"

—Not From Stone

For sometime now, season after season, I have been trying to understand the word "silviculture". Three dictionaries agree that "silviculture" is "the cultivation of forest trees". Such a definition leaves a lot to one's imagination. I had a sudden recollection of plowing corn as an Illinois farm boy.

Yesterday morning listening to that series of regional presentations — perceptive, highly informative, excellent — I picked up extensions of the definition, including "harvesting" and "regeneration". These, too, are rather open-ended.

The professional silviculturist these days appears to be engaged in a lot of things: research in a gamut of scientific explorations and adventures of the mind in everything from climate and soils to fertilizers, insects, acid rain, and the hole in the ozone, plus genetics and tree improvement; innovation in applying state-of-the-art technology to harvesting trees and planting trees; crisis conciliation in dealing with special interest extremists — a "now" breed of forest pest protected by law from extermination (I say this realizing today is a "kinder, gentler era".) The professional silviculturist,

like the old village schoolmaster causes one to wonder "How one small head can compass all he knows."

Rightly, instructively, the speakers yesterday morning stressed the importance of terminology — the urgent necessity for foresters to have command of a current vocabulary-in-common, as well as familiarity with historical antecedents.

Fine! elementary. But what of public awareness, comprehension, understanding, acceptance of what forestry professionals and technicians are doing? And why? There can be no forest management without purpose. Just what are those clearly stated purposes for each micro as well as macro site situation? Why cultivate forest trees? *Tell everybody.*

"Silviculture", what's that? Some of the public has a vague notion that houses are made of wood sometimes and that somehow paper is made from wood pulp, but they fail to see any real connection of these commodities with growing trees to sustain the supply of essential materials. A forest is where you go for a picnic. Trees? Trees just are — and don't cut one down. That's bad.

The enemy of silviculture is ignorance — and public indifference. No one is telling the story of forestry, of forest management, and its central role in human existence. No one is likely to tell it for you. It's your assignment as professional, dedicated, knowledgeable foresters. It is your Hippocratic oath.

Neither Congress nor State Legislatures are likely to appropriate large sums for publicity or promotion of even a worthy cause such as yours. You will need to be more innovative. Try to make full use of all the free public service time from the press and media that exists in every community. Give up at least half of the staff time talking with one another and go to the chambers of commerce, the service clubs such as Rotary, Kiwanis, Lions, Soroptimists, League of Women Voters, the Scouts, teachers' meetings, city council meetings when citizens comments are on the agenda, and talk to your neighbors. Have something constructive, informative to present and you will be

¹ Presented at the National Silviculture Workshop, Petersburg, Alaska, July 10-13, 1989.

welcomed and applauded – and in time understood for the great contribution you are making.

Most adults have heard of the multiple-use concept and the sustained yield principle, not that they fully grasp either, but try to. Make such practice, concepts, and guidelines real to them in their own community. Some will nod, even applaud with enthusiasm, yet not in full agreement. They will have a reservation, a “NIMBY” — Yes, but “*not in my backyard.*”

Communication with the public must be a high priority item in your everyday workload. Somehow there must be developed a sharper awareness of a fundamental fact of life: Historically all wealth used by man stems from two primary resource utilization activities: AGRICULTURE and MINING. Agriculture, in simple terms is the source of food and fiber; it includes fish, animals, birds, trees, plants, berries, nuts, — anything that grows and can be renewed. Mining is the source of tools, equipment, building materials, and much of our energy supply, anything that is not renewable. To each of these, human beings add much value in an infinite variety of ways, but the creation of all new wealth, increasing the base of human wealth, derives directly from Agriculture and Mining. Let the population grow, while the basic supply of wealth is static and inevitably, inexorably the standard of existence deteriorates.

It doesn't make sense to build road blocks for some extraneous purpose or ego-trip in the path of either agriculture or mining. Ill-advised attempts to obstruct, to slow down, to stop, to weaken either basic human activity is merely costly at first, but ultimately destructive of the security and status of mankind. No growth is dying on the vine.

Today's extremists in special interest groups, the political activists, pretend not to know that their advocacy of ultra-extreme positions on issue after issue of their own concoction always drives up the cost of living for each of us, for at the same time it drives down economic production.

Why in action after action are scare tactics used — and embraced by the media egoists and irresponsibles? Why are We, the People so damn gullible? Scare tactics always drive up the cost of producing goods and services for consumers! That's us, We, the People who pay the add-on,. Why take extreme punitive action against producers and manufacturers? This is popular with our plethora of attorneys, sad to say. Entrepreneurs, even the giant multi-nationals have no treasure store to be raided; they have only what they get from consumers of their products. That's us, We, the People. Why beat ourselves over the head just to dig more out of our

own pockets to pay for what we use — plus the added costs of litigation? It doesn't make sense. Nor does Big Government have any treasure trove to distribute, except for what it gets from us, the consumers of government services and largess.

Taxes are ever unpopular, yet justifiable and essential to maintaining a civilized existence with a modicum, at least, of order, fairness, justice, balance, and human dignity. For such, together we pay, but why demand government to do what we can best do for ourselves? Why clamor for dependency, when we are a free, proud and independent people?

I say these things to you because you as professional foresters are among those on the front line of defense of a very precious way of life. Historically, the world's most extra-ordinary. In both subtle and not so subtle ways your good work *in the interest of improving the human condition* is under attack, clearly on the endangered species list.

Yes, sit down and reason together with whatever the opposition, but keep your powder dry. Be on the cautious side, alert and wary in analyzing suggested compromises to sound, science-based positions. Study every proposal or demand in depth. What is its probable long-term impact? Then ask a series of three simple questions, politely, of course:

A. Why do you think or suggest that? (The “Why” question about “What”.)

(After the response, if necessary ask...)

B. So what?

Then ask the third question,

C. Could you please specify? Name three?

Since among your tormentors, and there are some if only a small percent, there is little truth and less scientific knowledge, the three questions maneuver is calculated at least to give you a little breathing and thinking time. They could empty the field — and you don't need a lawyer to ask the three questions. If you have one who doesn't know enough to ask them, fire him or her.

For your good cause, advocate and promote. Be assured, Forestry is a good cause... research, management, and all else in your professional obligation. It is a fundamental enterprise for the betterment of the human condition.

Just now, far too much time and energy is being absorbed in having to *react* to socio-political pressures from the outside. Don't lose patience, or self-confidence or commitment to basic purpose. Take comfort in the refrain at the end of each stanza of "Deor's Lament", the oldest fragment of Anglo-Saxon verse we have today: "This, too, shall pass away."

Change is continuous and some time must be spent in coping with the present as well as understanding the past. The main thrust, however, must be toward the future. The true professional forester is thinking, projecting plans and concepts *at least eighty years ahead*. He is both strategist and tactician. Eighty years, that's two generations plus; Three would be better, a full century. There is risk in this.. but by the nature of their mission professional foresters are calculated risk-takers and not merely nit-pickers on today's bottom line.

"IF ONE SHOULD DREAM NO MORE,
WOULD THERE ANY DIFFERENCE BE
FOR THOSE WHO DO NOT DREAM —
OR EVEN THOSE WHO DO?
IF ONE MIGHT CLIMB
THAT LONE AND AWESOME,
RUGGED, ROCK-STREWN HILL
AND REACH THE VERY TOP
THE FAR HORIZON,
WHAT DIFFERENCE WOULD IT MAKE?
ONE NEVER KNOWS
UNLESS ONE TRIES.
COME ON! LET'S TRY."

— Christmas 1987

What I really wanted talk about tonight is long range, futuristic if you like — the Boreal Forest of Interior Alaska. In that splendid overview of regional forestry yesterday morning no one bothered to mention more than casually the vast timber lands of the North. Even the outstanding presentation by our Canadian colleague barely mentioned it, although perhaps three-fourths of the Circumpolar Boreal Forest of North America is

Canada's. With that big beautiful Douglas Fir in the front yard, why bother with those scrawny black spruce and aspen weeds in a far corner of the backyard? In a sense such limited perception could be a form of hy-grading.

Almost all of the remainder of the Boreal Forest of North America stands along the great river systems of Interior Alaska, the Yukon, the Tanana, the Kuskokwim, and their scores of tributaries. There is a tiny bit elsewhere in the northern Great Lakes area and northern Maine and more in Alaska adjacent to the Interior — in the upper Susitna and Copper River valleys. Yet ninety percent of the total Boreal Forest of the United States lies between the rugged, majestic Brooks range to the North and the spectacular Alaska Range, featuring Mt. McKinley, and a dozen or so of somewhat lesser peaks, to the South. The great ranges guard and protect the valleys of the Interior, the great green oasis of Pleistocene times that was surrounded by walls of ice but never glaciated.

The Boreal Forest of Interior Alaska is yet to be recognized for what it is, a great National treasure as well as a prized possession of great value to the State of Alaska and it's residents. In its extraordinary diversity of opportunity it offers exceptional economic as well as recreational potential. The Boreal Forest is much, much more than timber harvest. *It is a way of life* unmatched elsewhere in our land. It shares some of its attractive potential with other Northern regions of the Circumpolar world; Especially the Yukon, Northern Alberta, Northern British Columbia and a portion of the Northwest Territories, yet it can lay claim to distinctive advantages of its own, such as strategic location on today's geo-political center stage.

It has been conjectured by some scientists of considerable credibility that extensive and intensive studies of the Boreal Forest of Interior Alaska could likely produce more basic data of future significance for the Nation's well-being than comparable efforts of all of our other National forest regions combined. I do not boast. Amazingly enough, in fact an astounding reality — there is no National Forest anywhere in the vast Interior of Alaska. There is everything else: National Parks and monuments galore, wildlife refugees, sanctuaries, wild and scenic rivers, wilderness areas, and an assortment of non-descript land withdrawals too numerous to mention.

Interior Alaska has been victimized and exploited by special outside interests. There remains, however, at least twenty-two million acres of timber lands, a good bit of which has been identified as having very good immediate commercial potential. These millions of acres cry out for state-of-the-art Forestry management.

There is no such thing in being. The Boreal Forest is so very different that modern practices successful elsewhere can seldom be transferred to it. A whole system of management must be devised, tailor-made for the Boreal Forest of Interior Alaska in all its micro-climatic complexity.

In Russian the term "Taiga" is used for the enormous USSR Northern Forest. call it "Boreal" or call it "Taiga" yet remember — and this may startle you — remember that the tundra is, indeed, fragile, but the Taiga is tough. It is a survivor with a phenomenal resistance factor and an exceptional capacity to endure and rebound from extraordinary climatic extremes. If the Taiga were not tough, growing things such as trees, would not be there in the first place. Look at the geological story, the paleontological story, the biological story, the climatological story, the ecological history. Fascinating!

The Taiga, our beloved Boreal Forest, must never, never be abused, but it must also be used intelligently or it will degenerate over time, perhaps slowly self-destruct. The key acronym for the Boreal Forest of the Interior is USE: Utilization, Stabilization, Enhancement. This adds a new dimension to the multiple-use concept and sustained yield principle. This is *total* utilization of the timberland for the ultimate improvement of the human condition. This is recreation, re-recreation, harvesting of wild berries and mushrooms, beekeeping, the gathering of flowers, herbs, roots, bark, fungi — whatever, for herbal-based pharmaceuticals; this is game-ranching, wild life in a natural setting, watershed management, range management, as well as surplus timber harvest.

And the primary thrust is to leave everything a little better than we found it. "A man's reach should exceed his grasp, or what's a Heaven for?" (Browning)

The Boreal Forest of Interior Alaska may be the *only* place where the U.S. Forest Service dare undertake a scenario that will require at least eighty years to stage fully.

A tiny beginning very much worthwhile has been made by the Institute of Northern Forestry operating from the Fairbanks Campus of the University of Alaska, America's premier center for research and advanced studies of the North. Yet the enterprise languishes in a prolonged infancy, meagerly and casually supported, seemingly as an afterthought — much as in the case of the USDA's oldtime curious arrangement known as the sub-unit on Arctic and Tropical Agriculture. I am old enough to remember those good old days of ignominy — benign neglect, if you prefer.

Were I Emperor of the Universe — at my age I dare not aspire to anything less — my first priority would be a gentle but firm directive to the U.S. Secretary of Agriculture and his deputy head of the U.S. Forest Service: Establish the Taiga National Forest, or the Boreal National Forest, in the Interior of Alaska. Then create a long-term research and demonstration program of the best possible timberlands management practice on the total utilization and enhancement principles — tailor-made for the conditions found in the region and for its residents.

Incidentally, if you actively involve the residents of all ages in the planning and thinking, you will likely find a lot of volunteer adult and youth corps type services available for labor intensive activities such as forest thinning, site preparation, seed gathering, propagation and planting. This would provide, also, a splendid opportunity for education and training of youth that would create an understanding to offset future public misunderstanding hazards. It might help also in recruiting a few good men and women for professional and technical careers in the U.S. Forest Service.

Establish a demonstration plot of at least 600 to 1000 acres each year for eighty years. This is your field laboratory. establish a tree improvement program from genetics to greenhouse to plant nursery to the micro-site for planting, testing and all of the associated research activities unfolding.

There is now a Tanana Valley State Forest of nearly two million acres. It has developed an operational plan but because of political entanglements and overlapping jurisdictions among a half dozen administrative agencies each with a separate and competing agenda, nothing at all is happening. Stalemate on the chess board. There is an urge to sweep off the pawns along with most of the top row of folk in the Seats of the Mighty and try to replace the lot with something called vision, leadership, statesmanship — This would certainly be an improvement over the Fraternal Order of Wealth Distributors now on the chess board of governance in Alaska.

Could a National Boreal Forest be created of present Federal withdrawals to match the size of the Tanana Valley State Forest? — So that the Eighty Year Research, Demonstration, Utilization, Enhancement project could get underway on a sound basis in full cooperation with the residents of the area, the State, and the Athabaskan Native Corporation, Doyon, Ltd., that privately owns over eleven million acres of the Interior, much of it timberland? Athabaskan leadership has stated a lively interest in the wild harvest of timberland resources other than lumber. "We are particularly interested in the pos-

sibilities of herbal based pharmaceuticals and natural-habitat game ranching.” They also agree with University scientists that the present productivity of the Boreal Forest can be doubled in a much shorter time frame than previously anticipated.

Here is your CHALLENGE, your OPPORTUNITY — your OBLIGATION and POTENTIAL. Co-op! Look North. Think North. Come North and enjoy with me “One More Day of Autumn”.

SHOULD THERE BE ONE MORE DAY OF AUTUMN,

LET ME SPEND IT IN THE HILLS,

THE WINDBLOWN HILLS OF LOESS,

THE GOLDEN BIRCH AND ASPEN

HILLS OF HOME.

LET ME SCUFF THE SUN-DRENCHED LEAVES

ALONG THE SLOPES

AND CLIMB THE CREST OF ULLRHAVEN

WHERE THE EAGLE NESTS.

LET ME STOOP ONCE MORE

TO PLUCK THE WINE-RED BERRIES

FROM THE SERE AND BRITTLE

REINDEER MOSS;

LET ME LISTEN TO THE STARTLED SQUIRREL

SCOLD THE WILLOW GROUSE

THERE IN GRACEFUL GLIDE

ALONG THE ROCK AND BRUSH-STREWN SLOPE.

SILENCE NOW. A COLD CRISP BREEZE.

PURE, CLEAR, CLEAN

AS THE ENDLESS ICE-BLUE SKY.

OUT OF THE MAUVE-RIMMED

EDGE OF TWILIGHT, A MOVING, SHIFTING V,

THE LAST WILD GEESE OF SUMMER

SOUTH BOUND FROM TUNDRA FEEDING GROUNDS

BEYOND THE YUKON.

THE TWILIGHT FADES;

THE LEADER’S POIGNANT CALL IS FAINTER NOW.

BETWEEN, THE GHOSTS OF YOUTH

DRIFT ACROSS THE DARKENING SKY.

UNFETTERED THE SPIRIT SOARS, THE MIND EXPANDS;

THE UNIVERSE IS ONE AND I AM OF IT.

THIS IS THE PERFECT MOMENT.

SHALL GOD PROVIDE ANOTHER LIKE IT?

– Not From Stone

This is the Forest Boreal

This is HOME.

Come share its joy, its fulfillment with me.

THE TIMBER PURCHASER-A PARTNER WITH A NEW ROLE

Lee Harry
Beaverhead National Forest
Northern Region
Dillon, Montana¹

INTRODUCTION

The Purchaser of National Forest timber is a partner with an expanding role in implementation of Forest Plans. This paper focuses on the job of new stand establishment, and how the Purchaser fits into that job.

As we implement Forest Plans we see a need to sculpt our forests into what we perceive as "best". The forests nature gave us are not necessarily the best mix for big game, water quality, or recreation.

We have some tools for creating the forest patterns we desire. One tool is fire. Another is timber harvest.

The change we want often involves replacement of mature stands with thrifty young stands. That requires several steps beyond harvest. It includes disposal of excess debris, soil scarification, elimination of damaging agents, and natural or artificial regeneration. The Beaverhead National Forest has been actively seeking out ways in which the Purchaser takes on a larger role in post-harvest treatments.

The Beaverhead is requiring Purchasers to do the following tasks:

1. Scarification and debris piling
2. Slashing of unmerchantable stems in clearcuts
3. Burning of logging debris

POST HARVEST GOALS

What are the goals we have when we treat a stand? Where do they come from? We have a Forest Plan which sets direction. An interdisciplinary team has boiled that down to some treatment needs for a particular stand or group of stands. A line officer has made a decision on what that piece of ground should look like in the future. The silvicultural prescription gives us detailed objectives for getting to that desired condition. It specifies things like the amount of debris to be left on site for nutrient cycling and seedling protection and the amount of bare mineral soil desired to provide seeding or planting spots. In the case of lodgepole pine, we may specify the amount and distribution of serotinous cones

necessary to assure natural regeneration. We may have goals for eliminating remnant trees which carry pathogens, like mistletoe.

Some whole tree harvesting operations accomplish most or all of these tasks as a result of logging.

CHANGED POST HARVEST CONDITIONS AND OBJECTIVES

Some post-harvest site conditions were different in years past than they are now. With conventional hand felling, limbing, and bucking in the woods we often had a real debris problem when harvest was completed. Tops and unmerchantable logs usually totaled many tons more than we wanted. Of course, back then, we figured we needed virtually no organic material left on site. The cleaner a unit looked, the more closely it fit our objectives. Now we know more about the value of woody debris. A cleanly piled or burned unit is a

poorly handled unit. We view woody debris as a resource which is important for nutrient cycling, seedling protection, erosion control and a host of other future stand needs. On the Beaverhead we are often struggling with how we can leave enough woody debris on site, rather than getting rid of any excess. Purchasers fell and bunch our lodgepole with feller-bunchers, skid the whole tree to central landings, and delimb and top it there. Unless we consciously monitor the amount of debris left, we can wind up with most of the unit being clean and pretty, but with a poor nutrient capital after logging.

We have changed our view on scarification a bit as well. "Potato patching" was a popular thing in some areas for a lot of years. In fact, we are still dealing with confusion on the part of some dozer pilers, due to the change. If 30% scarification was good, we often thought 80% was better. Especially with a species like lodgepole pine, which loves mineral soil and sunlight, we went for broke. Now we see advantages in leaving a mosaic of bare soil, interspersed with debris, and duff patches.

With that background, let's look at the shift to Purchaser work. Why the change?

¹ Presented at the 1989 National Silviculture Workshop, Petersburg, Alaska, July 10-13, 1989.

ADVANTAGES OF PURCHASER WORK

What are advantages of the timber Purchaser doing the post-harvest work?

1. The Purchaser often completes site preparation and brush disposal work more quickly than was the case with force account. Under the old routine, we closed a sale, or released a portion of the sale for brush disposal and site preparation work. Then we wrote a new brush disposal/site prep contract, advertised, and finally got a bid, often one season beyond the logging. We have improved on the system of being locked into the lowest bidder through negotiated contracts. However, we often were behind schedule due to the time taken to prepare, advertise, and award the contract. If we were counting on serotinous coned lodgepole pine for natural regeneration, a delay in piling did not just mean a regeneration delay. It often meant regeneration failure. The closed cones opened, seeds sprouted, and finally, we got a dozer with a brush blade in there. In some instances, we did such a good job of site preparation after the seedlings had sprouted that we destroyed all the naturals and bought into artificial regeneration. That was a big expense. With Purchasers being responsible to do site preparation and debris disposal, we tend to avoid those costly delays.

2. When we give the Purchaser a larger role in post-harvest work we provide an incentive for the him to make the complete job easier and more efficient. If his job stops at the time the unit is accepted for timber removal and erosion control, he doesn't benefit by cutting low stumps for easy brush disposal, or by knocking down some unmerchantable trees, or by a number of little things which could be part of his operation. He often wants to help, and if his bid includes cost of work beyond removing the timber, he can capitalize upon efficiencies.

We are specific about goals and objectives in our contracts. We try not to be as specific on how we expect the Purchaser to meet those objectives. For example, we often require a certain number of serotinous lodgepole cones per acre to be left on the site after logging. We also require a certain tonnage of large debris and a certain percentage of the area scarified to bare mineral soil. By allowing the Purchaser a stake in meeting all of these objectives, we see him becoming quite innovative in logging methods. He becomes concerned when summer logging results in only minor scattering of cones over the site. He may visit with the sale administrator to come up with options to keep more cones scattered over the unit. Often winter logging results in lots of small branch breakage. This results in many more serotinous cones being left on-site. He may ask his skidder operators to drive over the tops of felled trees to break off

cones. He may chose to have skidder operators take a bunch of tops back to the unit on each return trip into the unit. Perhaps more important than any other single item, is the incentive that Purchaser has to communicate with the Sale Administrator. Together, they have a job to accomplish. Nothing is left hanging for a later contract to try to correct.

3. With Purchaser required work, we can accomplish several objectives with one operation. For example, with the Purchaser assuming a larger share of the total job, we see him installing erosion control ditches, piling debris, exposing bare mineral soil, and removing mistletoe infected small trees all in the same operation. Only one piece of equipment is needed. Compare this to the force account method in which separate contracts are awarded for separate parts of the whole job. For example, under the force account method, the Purchaser completes the harvest, installs erosion control structures, and leaves. The Forest Service then awards a new contract for brush disposal and site preparation. The new contractor may or may not take care to reinstall the erosion control structures which the Purchaser installed. Suppose we do some nice things during sale administration, like deep ripping and scattering debris across temporary roads. A brush piling contractor may not understand what we did, and the Fuels Management Officer might not either. The potential for mixing up our objectives seems to be less if the timber Purchaser does the whole ball of wax.

SOME CHALLENGES IN REQUIRING PURCHASERS TO DO MORE WORK

Requiring the Purchaser to burn logging debris is the most controversial change we have made.

The Beaverhead has been requiring the Purchaser to burn logging debris for a couple of years now. Our experience has been good. Some points to consider are: Purchaser skills and equipment, Purchaser liability, Forest Service expertise and how we keep that current, and hidden costs to the Forest Service,

The Purchaser who buys most Beaverhead timber sales likes Purchaser burning. We are requiring Purchasers to do all but the most complex burning. That translates to the Purchaser doing most of the burning, since we have mostly tractor units, in which feller buncher and grapple skidders are used. This results in a large pile of debris at the mouth of the unit, sometimes a couple or three piles, or maybe a continuous string of debris along a temporary road location. Burning of debris in these situations is simple. Burning is done in the fall after we get some precipitation. The real variable is when that

fall moisture comes. A large concern is how long snow stays into the next spring. If it melts before the fuel is completely burned, we have the risk of fires coming to life next spring.

Smoke in May and June from dozer piles which the Purchaser lit last December means some extra expense for him. We have had a couple of situations which could have developed into real contract dilemmas. We did some things which eased the situation, and we learned some things which we can do better. In one instance, the Sale Administrator found a spring hold-over fire in a delimeter pile which the Purchaser had ignited the preceeding fall. The Sale Administrator contacted the Purchaser. It was inconvenient for the Purchaser to come with his engine to put out the fire, so the Forest Service handled it. We charged the Purchaser for the cost as an Operations Fire. Although this scenario sounds simple, we could have developed some real problems. The incident was a good case study to learn from. For example, the Purchaser's liability was quite low for an Operations Fire under the contract. We were lucky in that fire suppression costs were lower than the Operations Fire limit. We now set higher liability limits under the Operations Fire provision to reflect potentially higher costs of fire suppression in contracts which require Purchaser burning of logging debris. The incident also points out our reluctance to give up the fire control job. We let Purchaser inconvenience be a reason for the Forest Service to assume control responsibilities on that fire. We need to insist that the Purchaser bears the "inconvenience" of maintaining extra equipment and manpower to go along with the burning programs. This is a part of our new partnership. One of the positive aspects of Purchasers doing more of the post-harvest work is a realization that it costs money (and adds to overhead costs) to maintain a fire control organization. One of industry's questions about government costs and collections has been our overhead cost assessments. I think we will see a little more understanding as the Purchaser sees all those subtle costs, like having to maintain an extra engine for the time when a dry spring results in two or three hold over fires at once.

"When is a fire not a fire?" That one comes up if you don't have a mechanism to finally release the Purchaser from liability within a specified time. The Beaverhead has sent a letter to Purchasers and to Sale Administrators which clarifies our policy. Our Sale Administrators will accept all units for accomplishment of fire responsibilities, or specify which units are not acceptable for release, by June 30 of each year. As with all sale administration, this means our Administrators must be on top of the Purchaser's accomplishments, and what the ground situation is.

There have been some problems. Purchasers can't burn dozer piles until we get fall precipitation. By the time fall precipitation occurs, it's December first, and airshed restrictions come cropping up. Of course those same problems haunt the Forest Service burning program. The Purchaser might feel more pressure, since we hold a performance bond until the work is accomplished.

Another problem is that we don't get our bunkhouses painted as often as we like. We can't afford big brush disposal crews and budgets when the Purchaser is doing the work. That means we don't have the flexibility to send big force account crews off to Yellowstone National Park in fire emergencies, or have them maintain some trails on rainy days, or do the multitude of handy things that force account crews can do. On the other hand, we don't have the large crew to supervise. That means we can spend more time being technical experts.

Another problem is availability of firewood for the public. We seem to be settling this problem a little by requiring the debris burning to be delayed by up to 2 years. Our first Purchaser burning contracts didn't have that language, and we accomplished the objective sort of hit or miss. I'm sure there are some units in which we would like the wood saved for more than two years. One alternative we are trying is to keep debris burning responsibilities for areas within 200 feet of open roads. The rest is handled by the Purchaser.

Several fuel management people on the Beaverhead are uncomfortable with Purchaser burning. They see smaller budgets, and less on-the-job fire training of Forest Service people. When we get a fire bust, the dispatcher feels more comfortable if folks we send have spent some time rolling hose along a controlled burn, or have carried a propane torch to a few dozen brush piles. Those tasks give people a sense of fire behavior. We are losing some of that fire sense when Purchasers burn logging debris.

To compound the problem, we have not yet given Purchasers all the debris burning responsibilities. We keep the tough units. We expect our fuel people to handle the broadcast burn units, or units which are out-of-the-ordinary. These units are most likely to escape and have high costs.

We need to truly recognize the little courtesy things our fire dispatch office gives to the Purchaser who has burning responsibilities. Contract language is clear on how the Purchaser goes about burning. Contract provision C6.7 specifies that the Forest service gives approval to initiate burning, provides daily airshed information, provides information on precipitation amounts, notifies the County Sheriff, airshed coordinator, and interested per-

sons, and notifies the Purchaser when burning is to be suspended. We collect money to cover these costs. But we tend to do a lot of monitoring which is beyond our collection. I can't really prove this in figures, but I know that Forest Service folks spend time watching the job beyond what our collections cover.

Purchaser burning has been the most controversial part of the expanding role of Purchasers in post-harvest activities on the Beaverhead. It is working, but we need to keep after the problems as they surface. Perhaps the largest hindrance is our mind set.

CONCLUSION

Regardless of who does the work, we should make sure we get what we want. On the Beaverhead, we have enlarged the role of timber Purchasers in post-harvest activities. I hope we continue to view the Purchaser as a partner, helping us to establish healthy, well-stocked new stands.

**NEGOTIATED CONTRACTS:
NEGOTIATING FOR A BETTER
JOB IN SILVICULTURE**

Dave Cawrse
Silviculturist
Glacier View Ranger District
Flathead National Forest¹

ABSTRACT

In meeting management objectives on the ground, planting and thinning prescriptions have become increasingly complex. Awarding service contracts to the lowest bidder for planting and thinning has sometimes resulted in either poor work, claims, or both. Negotiated contracts offer the opportunity to have skilled contractors complete this work at a reasonable price. These contracts require project proposals from the contractor which indicate the experience, silvicultural knowledge, and type of business set up they have. These proposals are evaluated along with the price by a committee. Face to face discussions regarding the contractors technical approach and their price are part of the negotiation process. Contracts are awarded based on best proposals and best price. Negotiated contracts have allowed the Flathead National Forest to complete service contracts at a high quality level, reasonable price, little administration overtime, and with no claims through the 1988 field season.

INTRODUCTION

Management of the resources of the National Forest System lands has become increasingly complex. The main way that management objectives have been met is through manipulation of the vegetation by various silvicultural treatments. Silvicultural treatments of stands have either been done directly by the Forest Service through force account crews, or by contracting the project to the private sector. When contracting is done, many methods are available. What method to use depends on the complexity of the job, the workload of the unit, and the workload of the contracting unit.

This paper focuses on the use of negotiated contracts in accomplishing these silvicultural treatments. It is one of several types of contracts that can be used. A brief background is given on the use of negotiated contracts

on Flathead and Kootenai National Forests. Examples of negotiated contracts used to accomplish silvicultural treatments (in this case, planting and thinning) are discussed along with the pros and cons of using this type of contract.

BACKGROUND

Use of negotiated contracts is relatively new in the U.S. Forest Service. Prior to 1985, the Federal Procurement Regulations basically mandated the use of sealed bidding. With sealed bidding, the contract is awarded to the lowest bidder, usually without any up-front negotiations. With the enactment of the Federal Acquisition Regulations in 1985, negotiation and sealed bidding were put on equal footing with the contracting officer to make the choice as to which method best meets procurement needs.

Negotiated contracts have been used on the Kootenai National Forest for planting since the fall of 1985. In 1987 they were used for approximately 90% of the planting program. Four Districts are currently using them for planting, although they are used throughout the Forest for other types of contracts.

In 1984, the Flathead began using negotiated contracts on the Hungry Horse Ranger District. This was a multi-year requirements contract for planting. In 1988, all the other Districts used a negotiated contract for planting. These contracts followed the sample format for the standard regional bid contract, with evaluation criteria added. Quality control and self inspection are required in these contracts. Between 400 to 900 acres were involved in each of these contracts. In 1988, the Tally Lake Ranger District used this type of program to accomplish the thinning program. Prescriptions for free thinning were involved. The Kootenai first developed this type of thinning contract in 1986.

¹ Presented at the 1989 National Silviculture Workshop, Petersburg, Alaska, July 10-13, 1989.

APPLICATION OF NEGOTIATED CONTRACTS

Negotiated contracts involve a request for a proposal. A proposal consists of two parts: a business proposal and a technical proposal. After receipt of proposals, a technical committee is formed to evaluate the technical proposals from each contractor. The committee usually consists of the contracting officer, the contracting officer's representative, and 1 or 2 other people that are familiar with the project. At least one of the committee members should be a silviculturist, as he or she is the one that wrote the prescriptions that are being implemented in the contract. The exact role this committee plays is discussed later.

The *business proposal* involves estimates of the following:

Direct labor (This includes production per person, hourly rates, Worker's compensation, unemployment insurance, and fringe benefits. Crew names and titles can also be requested. This information is used to calculate the daily crew price. Using the number of acres to be thinned each day, the price per acre attributed to direct labor costs can be calculated.); *Self Inspection costs* (this is optional but would include hourly rate and total daily cost); *Tools and equipment*; *Supplies*; *Miscellaneous expense*; *Overhead* (Calculations and percentages are to be shown); and *Profit* (as a percent)

Total price per acre is then totaled. Thus price per acre is expressed as a function of all the above variables. It is often a point of discussion with the contractor, as the assumptions on what is profit, overhead, and production rates have been found to vary widely among contractors.

The business proposal is first evaluated by the contracting officer, and later by the technical committee after the technical evaluation is completed.

The *technical proposal* varies with the type of work being requested to be done. It includes a discussion of factors that indicate an understanding of the project, and a discussion of personnel and business organization, which overlaps with the business proposal. Price, however, is not included. A discussion on quality control may also be required. The following is an example of questions on a technical proposal for a planting contract that an offeror would address:

1. Technical Approach

- a. Percent of Planting Quality Guaranteed.
- b. Spacing.
- c. Planting Spot Selection (Micrositing).
- d. Quality Control.
- e. Production Plan.
- f. Tree Care.
- g. Contractor Inspection System.

2. Record of Past Performance

List contracts, contracting officer, telephone number, overall planting quality, and any defaulted units for the last two years.

3. Organization

- a. Key Personnel.
- b. Size and Capability.
- c. Recruiting Plan (including how problem employees are handled).

The technical proposals are evaluated and ranked as to their degree of acceptability by the technical committee. The committee does not have access to the pricing portion of the business proposal during the technical evaluation process.

The negotiation process consists of evaluation of the technical and business proposals, negotiation, further negotiation, and award. This process takes a minimum of 30 days. The following are the steps and guidelines given to the technical committee by the contracting officer (L. Steele, 1989). During this time, no information is to be given to anyone outside the technical committee without prior approval of the contracting officer. All questions are to be referred to the contracting officer until award is made.

1. Evaluate each proposal by yourself without discussion with others. Adhere to the following evaluation points:

- a. Evaluate the proposals in an unbiased manner. No outside information is to be introduced.
- b. Use descriptive, precisely worded narrative to describe strong points and weak points.
- c. Remember, you may be asked to explain your rating by an offeror in the debriefing process.
- d. Prepare a separate list of questions you would like to ask each offeror as you review the proposal.

e. Avoid:

- (1) Technical leveling - pointing out weaknesses which result from offerors lack of diligence competence, or inventiveness. This usually becomes a problem when three or more rounds of discussions are held.
- (2) Technical transfusion - disclosure of technical information from one offeror or proposal to another.
- (3) Auction Techniques - indicating a price one has to meet, telling offeror his price standing, or otherwise disclosing pricing data.

2. When individual evaluations are complete, compare evaluations with each other and prepare a summary evaluation.

3. The summary evaluation is reviewed with the contracting officer.

4. Competitive range is established by the contracting officer after discussion of prices with the technical committee. It is the contracting officers responsibility to establish the competitive range but the advice of the technical committee should weigh heavily in this decision.

5. Items are specifically identified by the committee for clarification and discussion with offerors in competitive range.

6. Clarify and discuss with the offerors the identified items either in person, by telephone, or in writing. All members of the committee participate. (Face to face negotiations are preferred.)

7. Best and final offers are requested from offerors by contracting officer.

8. Reconvene and make final recommendation to contracting officer as to award.

9. Contracting officer awards the contract.

10. A debriefing of offerors is done as requested.

The ultimate goal of the negotiation process is an award made to that offeror whose proposal is technically acceptable and where the relationship between costs and benefits is the most advantageous in meeting management objectives. The critical factor in making any cost-benefit trade-off is not the spread between the technical rankings, but rather the significance of that difference. The significance of the spread in rankings is determined on the basis of what that difference might mean in terms

of performance and what it would cost to take advantage of it. Award may not necessarily be made to that offeror submitting the lowest offer. Also, award may not necessarily be made for technical capabilities that would appear to exceed those needed for the successful performance of the work.

Additionally, award may be made without further negotiations if the highest ranking technical proposal also has the lowest price. Usually, though, after evaluation of proposals, further oral or written discussions become necessary and are conducted as appropriate with all offerors whose proposals are within the competitive range.

DISCUSSION

Negotiated contracts have been used with varying degrees of success. The following generalizations can be made as to the advantages and disadvantages of using negotiated contracts (L. Steele, 1989; J. VanDenburg, 1989; S. Wirt, 1989; J. Schutza, 1988).

Advantages:

1. A better relationship appears to exist between the contractor and the contracting unit.

Negotiated contracts provide a forum where the contractor and the contracting unit can meet and discuss the technical and business proposals before the contract is awarded. This usually clears up any misunderstandings or incorrect assumptions, and may create a more trusting atmosphere. This type of discussion is not allowed in a sealed bid contract until after award which is usually too late.

2. The negotiated process provides a way to eliminate contractors with a history of problems and failures, ones that lack experience or knowledge on how to do the job, or ones that are extremely high or low priced.

Contractors that do not have the knowledge or have shown a history of defaults or other problems would be given a low score on the technical proposal. If they rank significantly lower than other contractors, they may be eliminated from further negotiations. Similarly, if a contractor is extremely high or low priced as compared with the other contractors, that contractor may be eliminated.

3. Administration may be simplified.

After entering into discussions during the negotiation process, both parties should have a good understanding of the requirements of the contract. This understanding should eliminate many of the common ad-

ministration problems encountered with a sealed bid type contract.

Administration can even be further reduced when a self inspection system has been specified in the contract. Whether this truly occurs depends on the amount of trust the District has in the contractor's inspector. (Related to trust is disadvantage number 4). On some districts, administration costs have been significantly reduced. Under a sealed bid contract in 1987, the Tally Lake Ranger District spent 300 hours in overtime administration. In 1988, the same district spent 50 hours in overtime administration using a negotiated contract that required self-inspection.

4. Disputes appear fewer and easier to resolve.

Sealed bidding has tended to drive prices down and make contractors very competitive in order to get work. Many claims, however, have been filed with this type of contract where contractors attempt in some way to get extra compensation for units they had under bid. Although not enough data exists to make a statistically valid comparison, the results of claims on the planting contracts on the Flathead National Forest offer some comparisons. The last 8 negotiated planting contracts have not had a single claim involved with them. The 8 previous sealed bid contracts had 4 claims involved with them. Also, claims and change orders may be easier to resolve because of the availability of cost data in the business proposal. This data allows the contractor and contracting unit to agree on an equitable adjustment.

5. Silvicultural treatments that involve new requirements, complex silvicultural prescriptions, span several years, or involve lack of information can more easily be implemented.

New requirements in a contract, such as providing a self inspection system, appear to be better handled with a negotiated contract as the negotiations provide an opportunity to clear up questions in an area that's relatively new to contractors and the contracting unit or both. Complex silvicultural prescriptions, such as free thinning which require the contractor to have a good working knowledge of species identification, vigor, growth characteristics, and insect and disease problems, can be addressed in the technical proposal and discussed between the contractor and technical committee. On the Miller Creek Demonstration Forest on Tally Lake Ranger District, all thinning in 1990 will be done through a negotiated contract to ensure a complete understanding of what needs to be done on the ground. Multi-year contracts that involve some uncertainty on some variables or as to where

units will be located may best be handled through a negotiated contract. A multi-year contract has a higher level of risk associated with it and therefore may increase the price. A negotiated multi-year contract may provide an opportunity to increase trust and reduce misunderstandings, and may lead to lower prices.

6. Discussions with the contractor on the technical and business proposals have given insight as to how operations, expenses, profit, and risk are viewed by the contractor. This may lead to cost effective silvicultural prescriptions and to the development of better contracts.

Some contractors define their profit and overhead differently, which may account for differences in price. Other factors that are significant to the price can also be discussed. For example, going from a planting spot preparation (scalp) of 12 inches to a scalp of 24 inches costs about \$30 per acre. Silviculturists may want to carefully consider requiring scalping rather than routinely requiring it. This would result in a more cost effective prescription in meeting management area objectives. Another type of contract being developed on the Flathead for planting involves the use of cost categories. This is based on some of the information that has been obtained from negotiated contracts. In a cost category contract, the contractor would bid according to spacing, scalping requirements, and stock type. These appear to be the most significant cost variables. This type of contract appears promising for multi-year contracts as it reduces risks involved with obtaining a single price for all units.

Disadvantages:

1. More time up front is needed to complete and award a contract.

Evaluation of the technical and business proposals takes time for the contracting officer and the committee. From the time of advertisement to award takes a minimum of 30 days under a negotiated contract, while it takes a minimum of 10 days under a sealed bid contract. Also, due to the time needed to prepare the contract, the field units must prepare the specifications and submit to contracting one month earlier when compared with a sealed bid contract.

2. Technical proposals may become indistinguishable.

If the same questions are asked year after year, the technical proposals may be hard to evaluate. That is, all the proposals may look the same. In that case, one

must make sure the right questions are being asked. The more specific one can be in asking questions, the more sure one can be of the final product. As a bottom line, levels of experience and past history of failures or problems will still show up to distinguish one proposal from another.

3. Award price of a negotiated contract may be higher than sealed bid contracts.

Again, no statistics are available for a comparison. It appears, however, that costs are generally up to 10% higher than sealed bid contracts.

4. Contractors have had difficulty finding qualified inspectors. This may increase administration time.

This disadvantage applies to those contracts requiring self inspection systems. Inspectors are not as easy to find as contractors had planned when negotiated contracts for planting started on the Flathead in 1988. The Forest Service has had to closely watch some of the inspectors that the contractor hired, and, in some cases, actually provide training. Administration time increases when there is a lack of trust or when actual training is needed for the contractor's inspectors. Remember, however, that self inspection is in its infancy and constitutes a radical departure from the way the government has done business in the past.

Other points:

Costs and benefits need to be carefully considered before using a negotiated contract. Negotiated contracts involve more up front time and may cost slightly more. This should be weighed against time and dollars saved in administration and claims. Also a better quality job appears to be accomplished on the ground. Other factors that need to be considered are the workload of the contracting unit, since negotiated contracts require more time to award.

Negotiated contracting largely follows the theory on principled negotiation, as outlined by Roger Fisher and William Ury (1981). In principled negotiation, one establishes goals at the outset of negotiations. During negotiations, one focuses on interests, and not positions. Proposals are discussed on their merits, and decisions are reached based on reason, not power. In the past, sealed bid contracts have sometimes resulted in positional bargaining, where resolving claims has been a contest of wills and has resulted in anger and resentment with both parties. Negotiated contracting provides a refreshing departure from positional bargaining, and offers a way

to reach a fair price while respecting the interests of both parties.

SUMMARY

Negotiated contracts are another tool to get the job done. Through principled negotiation, discussions take place between both parties on the merits of proposals in order to reach a fair price. Negotiated contracts seem to be better suited where new or more complex situations exist, such as implementing a self inspection system, including several years in a contract, implementing a complex silvicultural prescription such as free thinning, or where lack of information exists.

Experiences on the Flathead and Kootenai National Forests have indicated that while negotiated contracts cost more up front to prepare, evaluate, and award, several advantages exist. These include better relations with the contractor, elimination of inexperienced or incompetent contractors, generally easier administration of a contract, fewer claims, and easier implementation of silvicultural treatments where new or complex situations exist. Additionally, some insight has been gained as to what contractors consider significant to their costs, which will be helpful in preparing other types of contracts in the future and in developing cost effective silvicultural prescriptions.

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REGENERATION OF SOUTHERN HARDWOODS:

SOME ECOLOGICAL CONCEPTS

David L. Loftis
Research Forester
Southeastern Forest Experiment Station
Bent Creek Experimental Forest¹

ABSTRACT

Classical concepts of post-disturbance succession through well-defined seral stages to a well-defined climax stage(s) are not a useful conceptual framework for predicting species composition of regeneration resulting from the application of regeneration treatments in complex southern hardwood forests. Hardwood regeneration can be better understood, and more useful prediction models can be developed, using the concepts of initial floristic composition and vital ecological attributes.

INTRODUCTION

In the ecology, silvics, or silviculture courses that most if not all of us attended, we studied concepts associated with forest succession, which has been a major area of study in ecology for more than 70 years. Attempts to explain successional phenomena have created a rich body of literature that I will not attempt to review here. It is sufficient to say that there are several schools of thought on what succession is and how it should be studied. The classical concept of succession includes seral stages leading to a climax(s). My own conclusion, based on the literature from ecology and forestry, is that this concept creates more confusion than understanding when it is applied to silvicultural systems and regeneration methods in southern hardwood forests. For example, it is unlikely that any consensus could be reached on a classification of 'climax' vegetation in the Southern Appalachians. Further, identical treatments in stands with very similar species composition growing on very similar sites can produce widely differing species composition of regeneration (Loftis 1989). And among stands with very similar species composition growing on very similar sites, different treatments have resulted in very similar species composition of regeneration (Loftis 1983a). So, classifying seral stages and linking them

with particular kinds and levels of disturbance also present difficulties.

Rather than force observed responses into a conceptual framework in which they apparently do not fit, more effort must be directed at understanding the process of regeneration. I therefore will discuss two concepts—initial floristic composition and vital attributes—that may form the basis for understanding regeneration in managed hardwood forests. My focus will be on species composition of regeneration, where regeneration is the result of planned, recurrent disturbance designed to create a new age class of trees. Therefore, the spatial scale to which I apply these concepts is the stand, and the temporal scale is the rotation length.

INITIAL FLORISTIC COMPOSITION

The first of these concepts was proposed by Egler (1954). He presented two contrasting patterns of vegetation development following abandonment of agricultural land. The first pattern he called 'relay floristics,' in which groups of species appear and are replaced by other groups of species until some relatively stable community is attained. As an alternative, he proposed another pattern he called 'initial floristic composition,' in which the site receives an initial load of propagules and a plant community develops without additional input of new individuals. The apparent dominance of different groups of species is the result of differential development or growth of different species or groups of species. Regardless of its applicability to old-field succession, many investigators have recognized, either explicitly or implicitly, the broad applicability of the initial floristic composition pattern to hardwood stand development following disturbance (e.g., Oliver 1981, Leopold et.al. 1985, Shugart 1984, Drury and Nisbet 1973). The essential feature of the initial floristic composition concept that makes it useful for modeling is that the individuals of species that form the dominant canopy 50 to 100 years

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after disturbance come from the initial load of propagules. A corollary to this concept is that variations in species composition 50 to 100 years after disturbance may result from variations in this initial load of propagules. We know that for hardwood stands the initial load of propagules after harvest cutting will be comprised of:

1. New seedlings
2. Advance reproduction
3. Stump or root sprouts.

VITAL ATTRIBUTES

It is important, then, to understand more about this initial load of propagules. Noble and Slatyer (1980) suggested that species composition of stands that develop after disturbance could be predicted from 3 vital attributes of species:

1. The method of arrival or persistence of a species at a site during and after a disturbance.
2. The ability to establish and grow to maturity in the developing community.
3. The time needed for an individual of a species to reach critical life stages.

Because of time constraints, I will discuss only the first two of these vital attributes. The first can be illustrated by grouping species by their primary mode of arrival or persistence during and after disturbance. On mesic sites in the Southern Appalachians, for example, new seedlings established during or soon after disturbance are an important source of regeneration for only a few species (Table 1).² Most species are advance-growth dependent, i.e., they *must* persist as advance reproduction or develop from stump or root sprouts. A species' shade tolerance generally indicates the likelihood that its advance reproduction will be present on the site as we approach a regeneration cut. Shade-intolerant species are unlikely to be present as large advance reproduction. To the extent that shade-intolerant species can germinate under closed stands, the establishment-mortality cycle tends to be fairly rapid. Shade-tolerant species are more likely to be well represented as large advance reproduction or larger advance growth. Species listed as intermediate in shade tolerance can usually germinate and survive for a few years under closed stands, but typically show little development. For example, northern red oak (*Quercus rubra* L.) seedlings become established after

good seed crops, but survival of a cohort is likely to be less than 10% after 10 years, and those that do survive will have grown very little (Loftis 1983b).

Generalizations about seedling population dynamics based on species' shade tolerance should be viewed cautiously. We need to know much more about the dynamics of seedling populations of individual species under mature stands and the factors that influence these dynamics.

Given some initial load of propagules, how do we approach the second vital attribute, the ability to grow to maturity in the developing community? Again, let me use northern red oak to illustrate one approach. Recall that red oak is an advance growth dependent species. It is well established that growth of red oak stems after harvest is related to the size of the advance reproduction (Sander 1971, 1972). Based on this information, we have developed from experimental data a model that relates the probability of a stem becoming dominant or codominant (dominance probability) in the next stand to its preharvest basal diameter and the quality of the site on which it grows (Loftis 1988a). The dominance probability increases with increasing preharvest basal diameter and decreases with increasing site quality. We attribute the inverse relationship with site quality to the increasing level of competition with increasing site quality. If we have knowledge about the numbers in each size class of red oak that are present in the stand at the time of harvest, we can roughly predict the number of dominant and codominant red oaks that will be present in the next stand. Similar models have been developed for oaks on more xeric sites (Sander et al. 1984).

As I have suggested in an earlier paper (Loftis 1989), this probabilistic, population-based approach is quite attractive for predicting the amount of a single species to be expected in the stand that develops after harvest. However, for predicting species composition in multispecies stands, there are several drawbacks to this approach. The most serious, in my view, is that competition is considered implicitly in the model as a function of site quality. One simple approach to modeling species composition in multispecies stands, which explicitly considers competition, is to rank relative post-harvest performance by species and regeneration source. Applying such a ranking to information collected from stands prior to harvest, say using 0.01 acre plots, would provide a basis for predicting species composition. The expected species composition on each plot, based on the ranking, could be combined to provide a picture of stand-level species composition.

² See also Beck (1988), Kelty (1988), and Johnson (1989).

TABLE 1. Reproduction sources and shade tolerance of some Appalachian species.

Regeneration from new seedlings established after cutting	
Species	Shade tolerance
Yellow-poplar	intolerant
Sweet birch	intermediate
*Black cherry	intolerant
Yellow pines	intolerant
Advance-growth-dependent species (from advance reproduction and stump sprouts)	
Red oak	intermediate
White oak	intermediate
Chestnut oak	intermediate
Black oak	intermediate
Scarlet oak	intermediate
White ash	intermediate
*Black cherry	intolerant
Cucumbertree	intermediate
White pine	intermediate to tolerant
Hickories	intermediate to tolerant
Basswood	intermediate to tolerant
Red maple	intermediate to tolerant
Sugar maple	tolerant
Beech	tolerant
Buckeye	tolerant
Hemlock	tolerant

* Based on detailed preharvest inventories and stem analysis data, black cherry sometimes regenerates successfully from new seedlings, while in other cases, it appears to require advance growth to compete successfully (Loftis, unpublished data). The conditions under which these 2 regeneration strategies operate have yet to be determined.

SOME IMPLICATIONS FOR REGENERATION METHODS

If one accepts these concepts as a rational basis for understanding hardwood regeneration, then devising regeneration methods to influence species composition requires treatments that will effect changes in the initial load of propagules. These changes may involve discriminating against some regeneration sources, changing the size-class structure of regeneration sources, or some combination of the two. Again, consider red oak in the Southern Appalachians. As you might expect from the information I have already presented, red oak is difficult to regenerate. Successful regeneration depends on the presence of large advance reproduction in the initial load of propagules, but large advance reproduction will not develop in the absence of disturbance. We have devised a method to regenerate red oak that in-

volves treating midcanopy and lower canopy trees with herbicides about 10 years prior to overstory removal. This level and kind of disturbance simultaneously enhances the growth of advance red oak reproduction prior to overstory removal and eliminates sprouts from midcanopy and lower canopy trees from the initial load of propagules after overstory removal (Loftis 1988b).

FINAL THOUGHTS

I have drawn heavily on some of our work in the Southern Appalachians, but I believe these concepts apply generally to managed hardwood forests. I am optimistic that we will be able to develop, for managed forests, predictive models of species composition. In his excellent review paper, White (1979) emphasized the importance of understanding disturbance regime in studies of suc-

cession. He dealt with natural (non-anthropogenic) disturbance and its implications for species compositional dynamics on an indeterminate temporal scale. White suggested that disturbances can be described by such parameters as frequency, predictability, and magnitude. In "naturally" disturbed communities, a great deal of uncertainty can be associated with disturbance regime. In silviculture, however, we exert considerable control over the parameters of disturbance. If we can understand the effects of timing and type of disturbance, we will be able not only to predict predict species composition, but also to control it.

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THE EFFECT OF THINNING AND FERTILIZER APPLICATION ON WESTERN SPRUCE BUDWORM POPULATIONS AND HOST TREE GROWTH: IMPLICATIONS FOR DEFOLIATOR MANAGEMENT

Boyd E. Wickman, Chief Research Entomologist
and
Richard R. Mason, Principal Insect Ecologist
Forestry Sciences Laboratory, Pacific Northwest Research Station
LaGrande, OR
and
Thomas J. Savage, Washington State University,
Pullman, WA.¹

PREFACE

This paper should be viewed as a progress report. The data sets will not be completed and analyzed until late 1989. The results we present reflect the first four years of the study (through 1988). We plan to publish the final results in a series of four papers in a research Journal with other participants including; H.G. Paul, Forestry Sciences Laboratory, LaGrande, OR, R.H. Waring and K. Cromiak Jr., Department of Forest Science, Oregon State University, and R.C. Beckwith, Forestry Sciences laboratory, Corvallis, Or. Other cooperators include R. Dezellum, Silviculturist on the Malheur National Forest in 1984, Robert Dolph, USFS retired, and Iral Ragenovich, USFS, Region 6, Portland.

ABSTRACT

A cooperative silviculture study with Oregon State University and the U.S. Forest Service was carried out from 1984 to 1989. Small plots of grand fir, *Abies grandis* were thinned, thinned and fertilized with N, fertilized only, and left untreated. The treatments were replicated four times in a split-plot block design. Analysis of foliar N in 1986 showed that thinning did not alter any of the foliage chemical fractions measured, but fertilization at 350 kg per ha significantly increased N and free amino acids. Annual measurements showed that fertilized plots had a higher budworm density and significantly heavier female pupae than did the controls. Insect herbivore biomass was also significantly higher on both thinned and fertilized plots than on control plots. Percent defoliation, however, was significantly lower on the fertilized plots. There was also significantly more new shoot biomass produced on fertilized trees than on controls. Fertilized trees apparently did not respond by increasing defensive chemicals, but did produce more

foliage than could be consumed by the budworm and other herbivore larvae. Radial growth of fertilized trees was nearly double that of thinned and control trees. Forest fertilization may offer an alternative management technique in high value stands for defoliating insects like western spruce budworm. A large replicated fertilizer study was started in 1988 near LaGrande, Oregon to further test the technique.

INTRODUCTION

The survival, growth, and reproductive potential of herbivores is, in part, directly related to the quantity and quality of available food. The host plant can greatly influence not only the amount of colonization by an insect pest but also the natality and mortality (Van Emden and Way 1973). White (1974) postulated that the amount of available nitrogen early in a phytophagous insect's feeding cycle significantly affects early survival and eventual numerical increase in the population. The mechanisms of host plant resistance are varied; i.e., leaf toughness (Ghent 1960, Tanton 1962); phenological asynchrony (Eidt and Little 1968, Wickman 1976, Beckwith and Burnell 1982); nutritional deficiencies (House 1965, Mattson and Scribner 1987); feeding stimulents (Heron 1965); and, alleochemicals (Rhoades 1979, Cates 1980, 1981). This study is an investigation of the effects of silvicultural thinning and nitrogen fertilization on insect/plant interactions of a major defoliator of the mixed conifer forest, the western spruce budworm, *Choristoneura occidentalis*.

The broad objective of this study was to determine how the balance of carbon to nitrogen in a grand fir ecosystem affects the chemistry of emerging grand fir foliage and the growth of western spruce budworm larvae. In-

¹ Presented at the 1989 National Silviculture Workshop, Petersburg, Alaska, July 10-13, 1989.

creasing the availability of nitrogen by fertilization was expected to increase the amount of available nitrogen in the foliage and promote the growth of budworm larvae. Thinning was expected to increase carbon production in the leave trees, thereby increasing the synthesis of defensive compounds that inhibit larval growth. Growth and survival of spruce budworm larvae was expected to correlate with the balance of available nitrogen to available carbon in the grand fir foliage.

The specific objectives were to determine the effects of treatments on survival, development, and fecundity of the budworm population and their subsequent impact on the host trees.

METHODS

Study Area:

The experiment was conducted on a nearly level bench (1850m elevation) on the north slope of King Mountain about 30km northeast of Burns, Oregon. The forest, before the turn of the century, was mostly old growth ponderosa pine, *pinus ponderosa*, but after 1900, when fire control eliminated periodic fires, grand fir, *Abies grandis*, began to dominate the understory. Periodic logging of the overstory pine gradually reduced the pine dominance and by 1983, when much of the remaining pine overstory was removed, the site was dominated by dense clumps of 70-90 year old grand fir with a sparse scattering of old ponderosa pine.

The area receives about 50cm precipitation annually, mostly as snowfall in the winter.

The soil is a gravelly loam 30 to 75cm deep overlaying hard basalt and andesite with some soft to moderately hard tuffaceous interflow material. The soil surface is 10 to 30 percent covered with flat and angular rock fragments; the litter layer is 0 to 2.5cm thick and covers 40 to 60 percent of the soil surface. Soil pH ranges from 5.6 to 6.5 (Carlson 1974).

The area has a history of defoliator outbreaks. In 1965 it was sprayed with DDT to control an outbreak of Douglas-fir tussock moth. In 1982 defoliation by western spruce budworm was detected in the area and in 1983 it was sprayed with carbaryl. In 1984 populations of budworm were very sparse, but by 1985 budworm populations increased noticeably, either from resurgence of the population that survived the chemical treatment or from immigration of new adults or both.

Experimental Design:

A split-plot experiment was replicated on four 2.4ha blocks either across a forest road or adjoining each other. Thinning was the main plot treatment and fertilization the sub-plot treatment. In the summer of 1984, a random half of each block was thinned operationally by Malheur National Forest contractors. Trees were thinned to an 5.5m (18 ft.) spacing with the following restrictions: grand fir greater than 13cm (5 in.) DBH and any remaining ponderosa pine greater than 19cm (7 in.) DBH could not be removed, although trees up to 30.5cm (12 in.) that could not yield a 4m (13 ft.) log due to defect could be removed. Due to these restrictions the spacing throughout the thinned plot was not consistent. A random half of each thinning treatment (both thinned and unthinned) was hand-fertilized with 350 kg/ha (about 300 lbs./acre) nitrogen in the form of urea. Therefore, each block had four plots; a control, fertilized only, thinned only, and thinned and fertilized.

Five trees with DBH ranging from 8 to 20cm (3-8 in.) were selected in each plot as sample trees for foliar chemical analysis. Western spruce budworm and associated insects were sampled at midcrown with pole pruners and baskets from these trees and five additional trees per plot annually from 1986. At least 100 budworm pupae were also collected each year by beating lower branches. Egg mass density was estimated annually on branch tips clipped from the midcrown. Two midcrown branches from each of 10 trees per plot were used to visually estimate percent defoliation. Ten new shoots per branch were also clipped from these branches. These shoots were dried and weighed to obtain shoot and foliage biomass production estimates.

On June 23-24, 1986, 5-10 g fresh weight of current-year foliage was collected from the midcrown from each of the five sample trees, placed on dry ice in coolers and taken to Corvallis, OR for analysis of nitrogen (N), soluble sugar, free amino acid, starch, holocellulose, and lignin content.

Insects from clipped 45cm branches were collected in alcohol and taken to LaGrande, OR and separated by species, counted and related to branch surface area (m²), dried, and weighed.

RESULTS

Foliar Chemistry:

Thinning did not significantly affect any of the foliar fractions measured. Fertilization increased the concentration of free amino acids, total nitrogen content, and the ratio of free amino acids to total nitrogen, but decreased foliar starch content (figure 1).

Mean free amino acid concentration, and the ratios of free amino acid concentration to total nitrogen, sugars + starch, and lignin significantly correlated with male and female pupal weights.

Western Spruce Budworm:

Budworm populations re-invaded the area in 1985, reached a peak density in 1987, and declined from natural causes in 1988. There was a non-significant trend for higher densities of larvae on the thinned, fertilized, and thinned and fertilized plots from 1986 to 1988 (Figure 2). Dry weights of budworm larvae were recorded in 1987 and 1988. There was significantly more budworm biomass ($P < 0.05$) on the fertilized and thinned and fertilized plots than on the control and thinned only plots both years (figure 3). Fertilized trees also produced significantly ($P < 0.05$) heavier budworm pupae than the controls and in 1986 this was significantly ($P < 0.05$) correlated with N and free amino acids in the foliage.

Effects on Host Trees:

Visually estimated mid crown branch defoliation was significantly ($P < 0.005$) lower in fertilized plots in 1986 and 1987. In 1988 there was only light defoliation on all plots (Fig. 4). Significantly ($P < 0.01$) more new shoot biomass was produced on fertilized trees than on trees from thinned and control plots in both 1987 and 1988 (Fig. 5). Radial increment measured in 1987 on 10 trees per plot showed a slightly decreasing growth trend on trees in the control plots for the period 1984-1987. There were little growth changes in thinned plots but a significantly ($P < 0.01$) higher radial growth in the trees on fertilized and thinned and fertilized plots in 1986 and 1987 (figure 6). Expressed as an index to the control, radial increment of fertilized trees was nearly double the unfertilized trees in 1987.

DISCUSSION

Evidently changes in the carbon/nitrogen balance did not alter foliar defensive chemicals, but fertilized trees did produce more new foliage than budworms could consume. Fertilization increased radial growth rates even while the trees supported damaging levels of western

spruce budworm larvae. It has been hypothesized that trees in some situations optimize defense by allocating resources to growth rather than defensive chemicals in the expanding foliage. Perhaps grand fir growing on the sites studied is a high-resource adapted plant that maximizes its growth by minimizing its allocation to plant defense as suggested by Coley, Bryant, and Chapin (1985).

We visualize fertilization as an alternative management technique for western spruce budworm in high value stands. If fertilization increases the tolerance of host trees to defoliation for several years, that might buy enough time for natural regulatory factors to reduce budworm density to a non damaging level.

The last annual measurements were made on the King Mountain study during summer of 1989. The results of the five year study will be analyzed and reported as quickly as possible. In 1988 we also started a large, replicated fertilizer study in budworm infested stands just north of LaGrande, OR. In this cooperative study we will be taking an integrated forest management approach by examining the effects of urea plus two balanced fertilizer applications of N P K and S on budworm densities, natural enemies, root disease, mistletoe, tree growth, understory growth and utilization by big game and livestock, nutrient cycling processes in the soil and the economics of nutrient management in interior mixed conifer forests. Managing the budworm and perhaps other defoliating insects through soil nutrient management may be more economically attractive when the combined economic benefits of fertilization are considered.

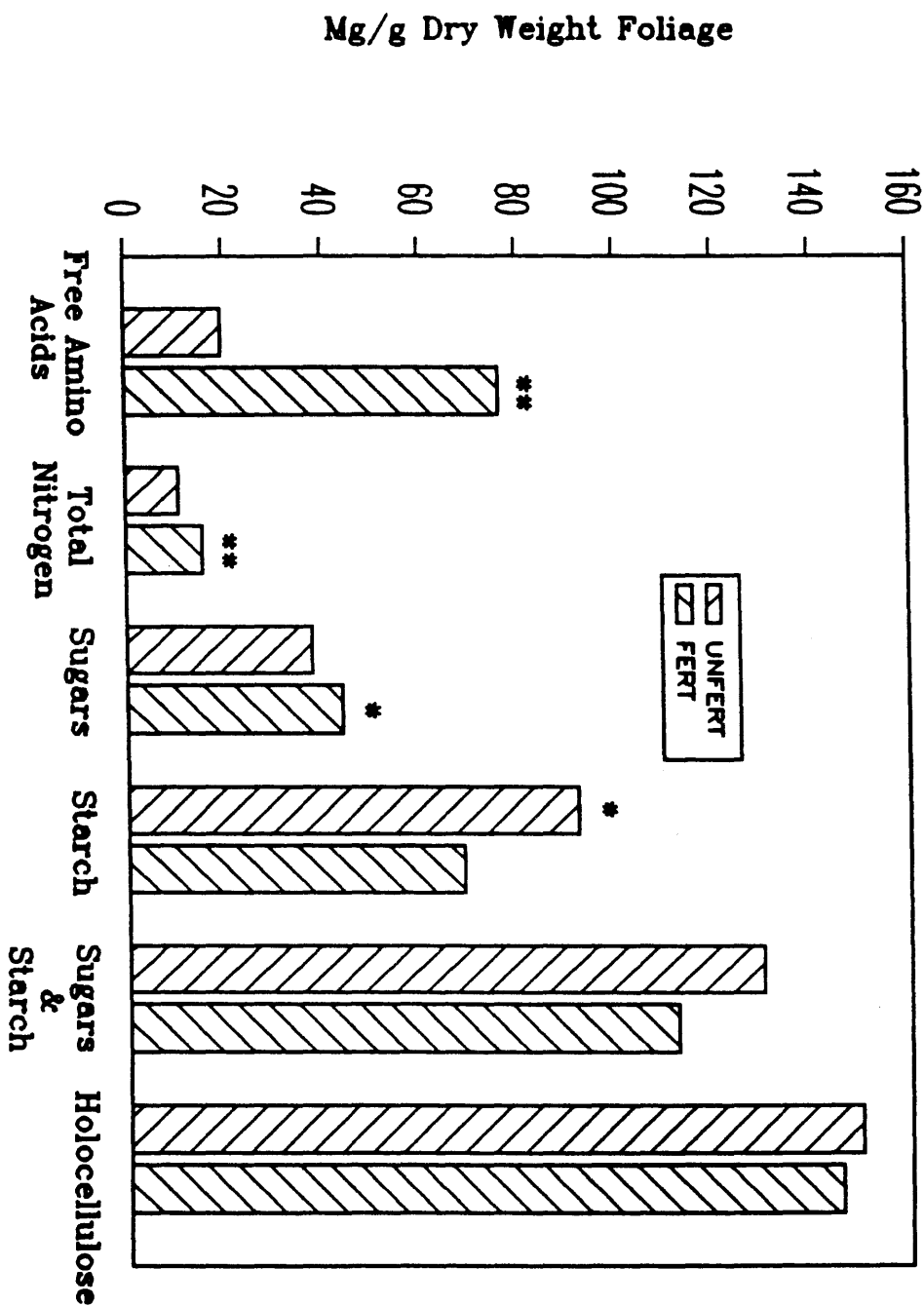
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Figure 1

Mean Foliar Concentrations of Chemical Fractions Mg/g in 1986 Needles Kings Mountain



** Significant at $P < .01$

* Significant at $P < .05$

Figure 2

DENSITY OF BUDWORM LARVAE

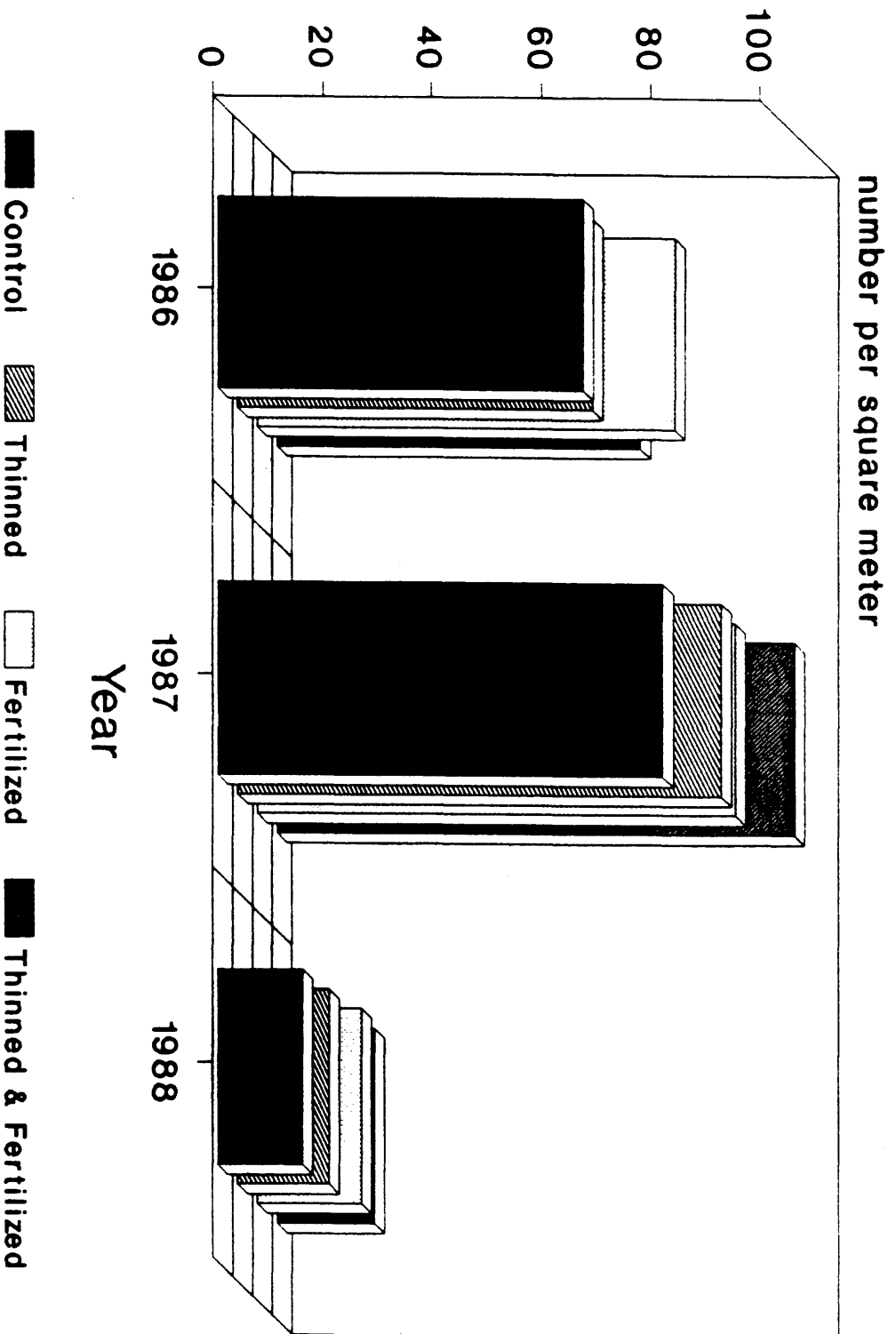


Figure 3

BIOMASS OF BUDWORM LARVAE

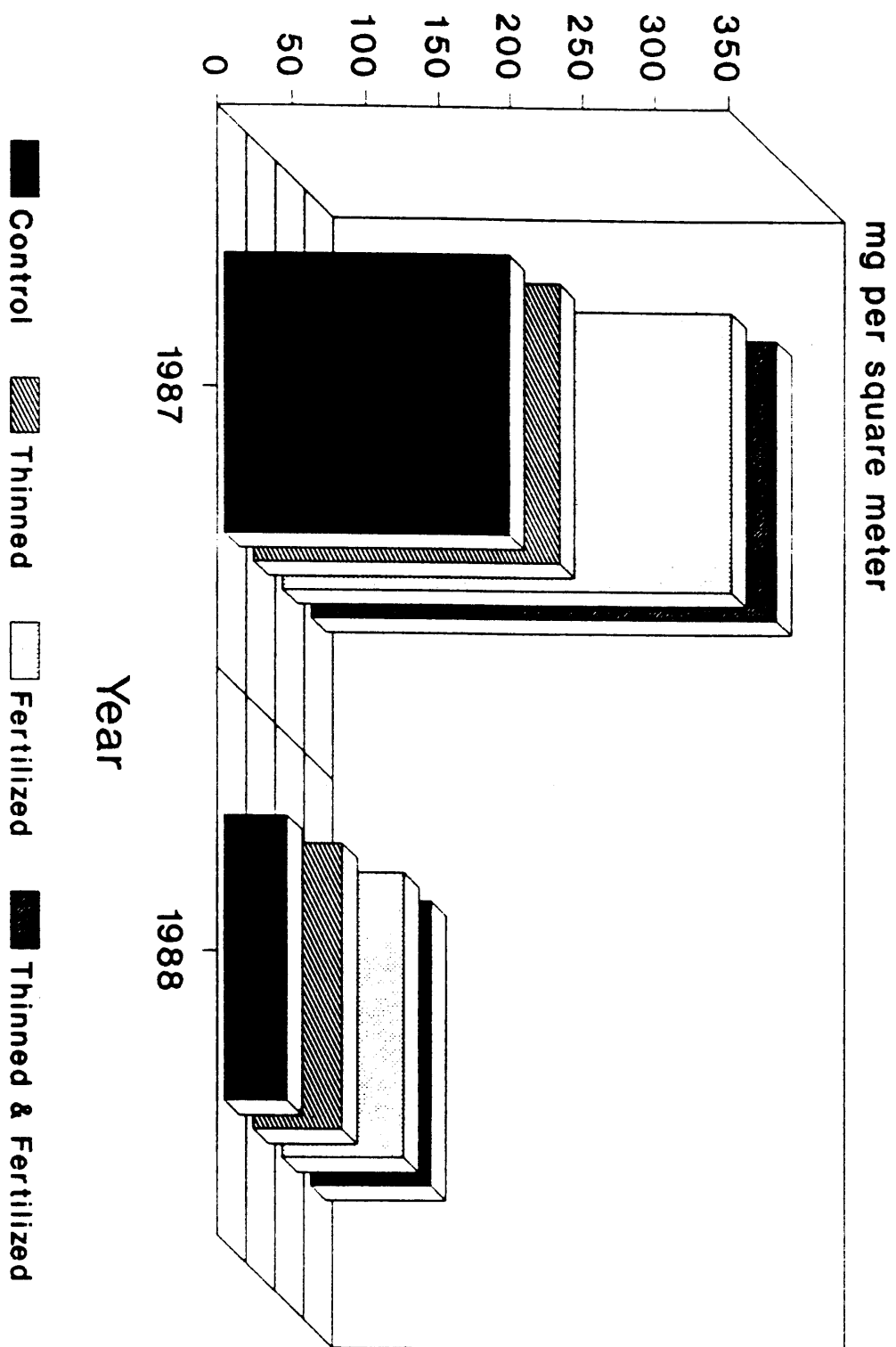


Figure 4

PERCENT OF TREE DEFOLIATION

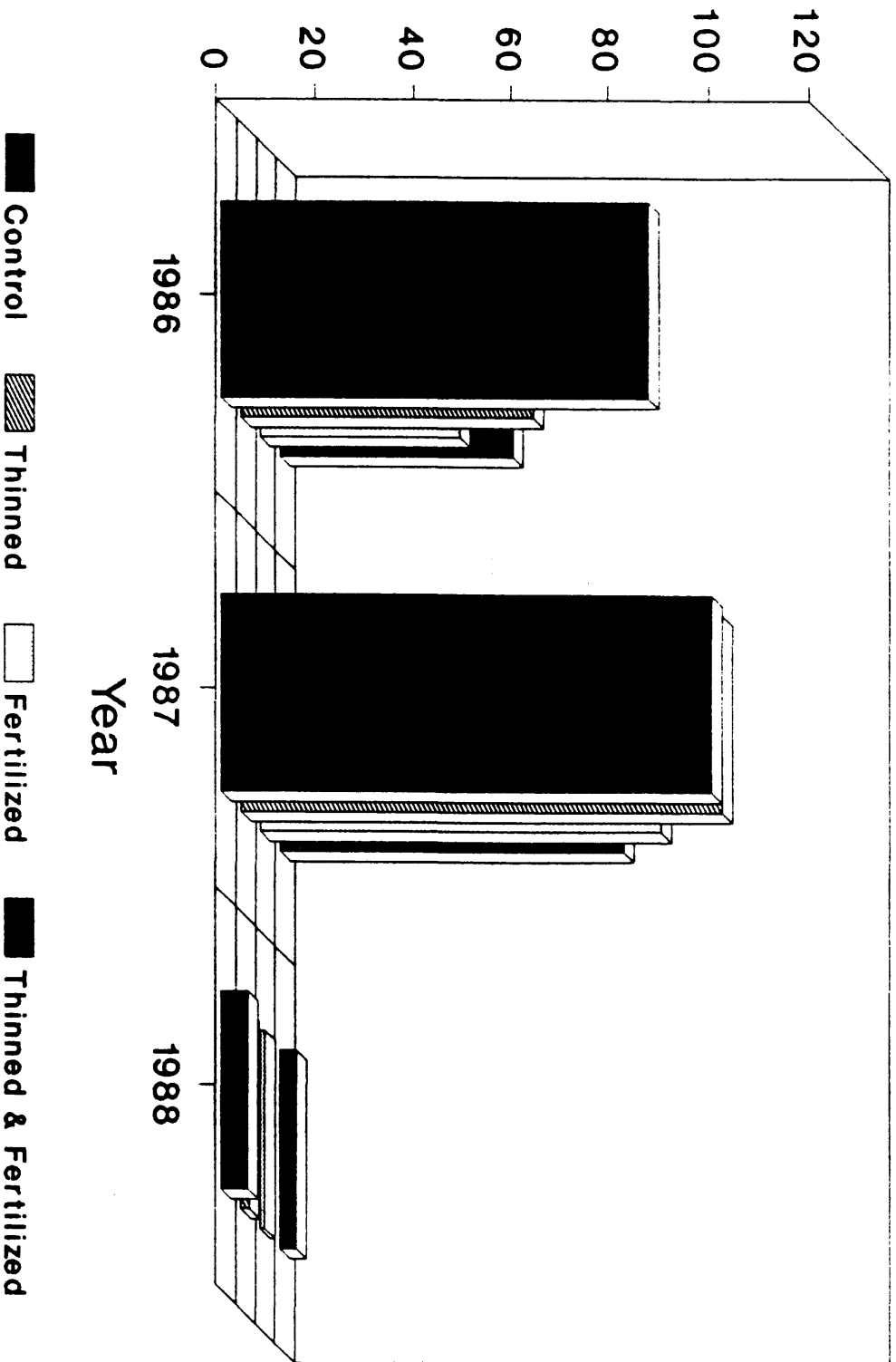


Figure 5

SHOOT AND FOLIAGE BIOMASS

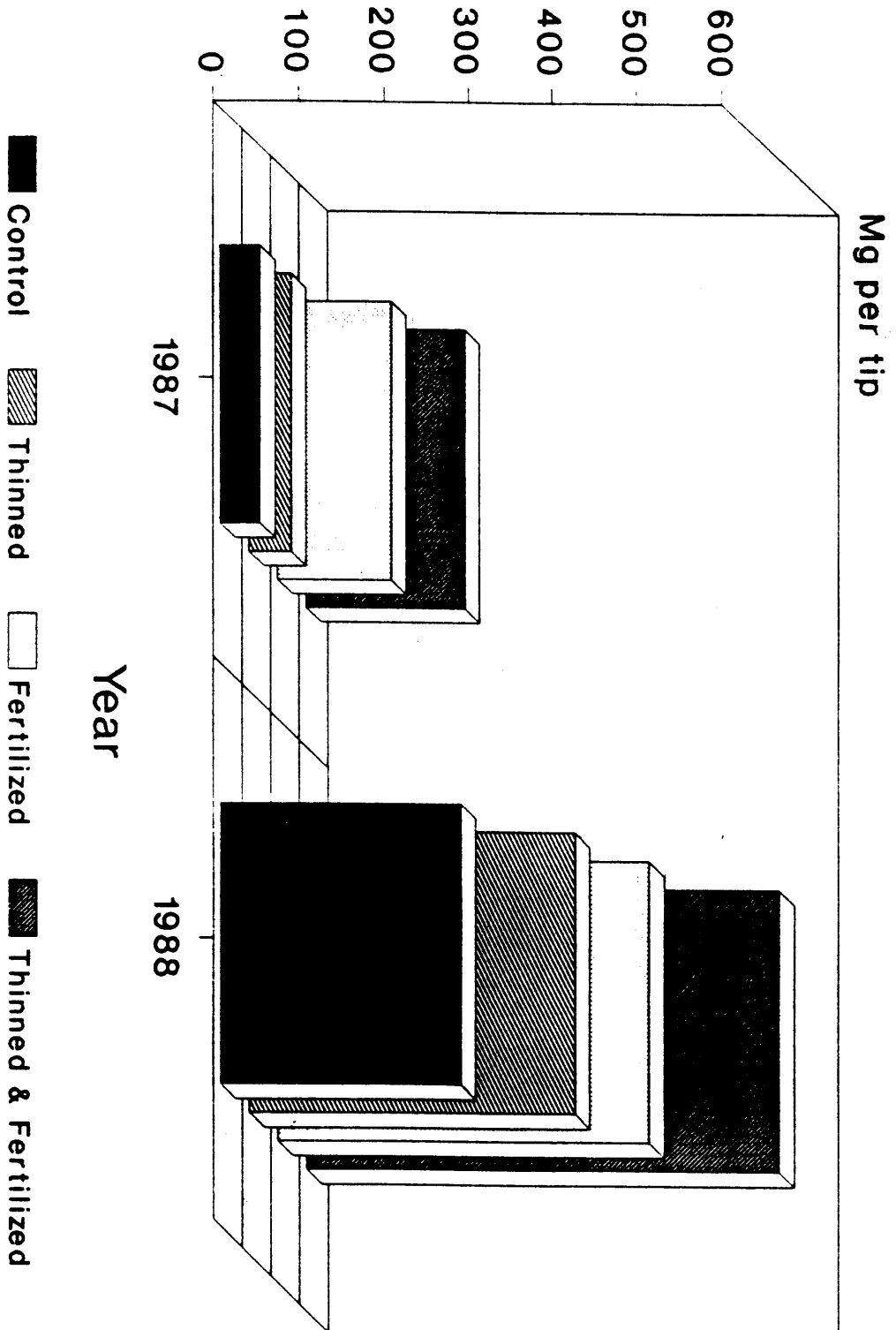
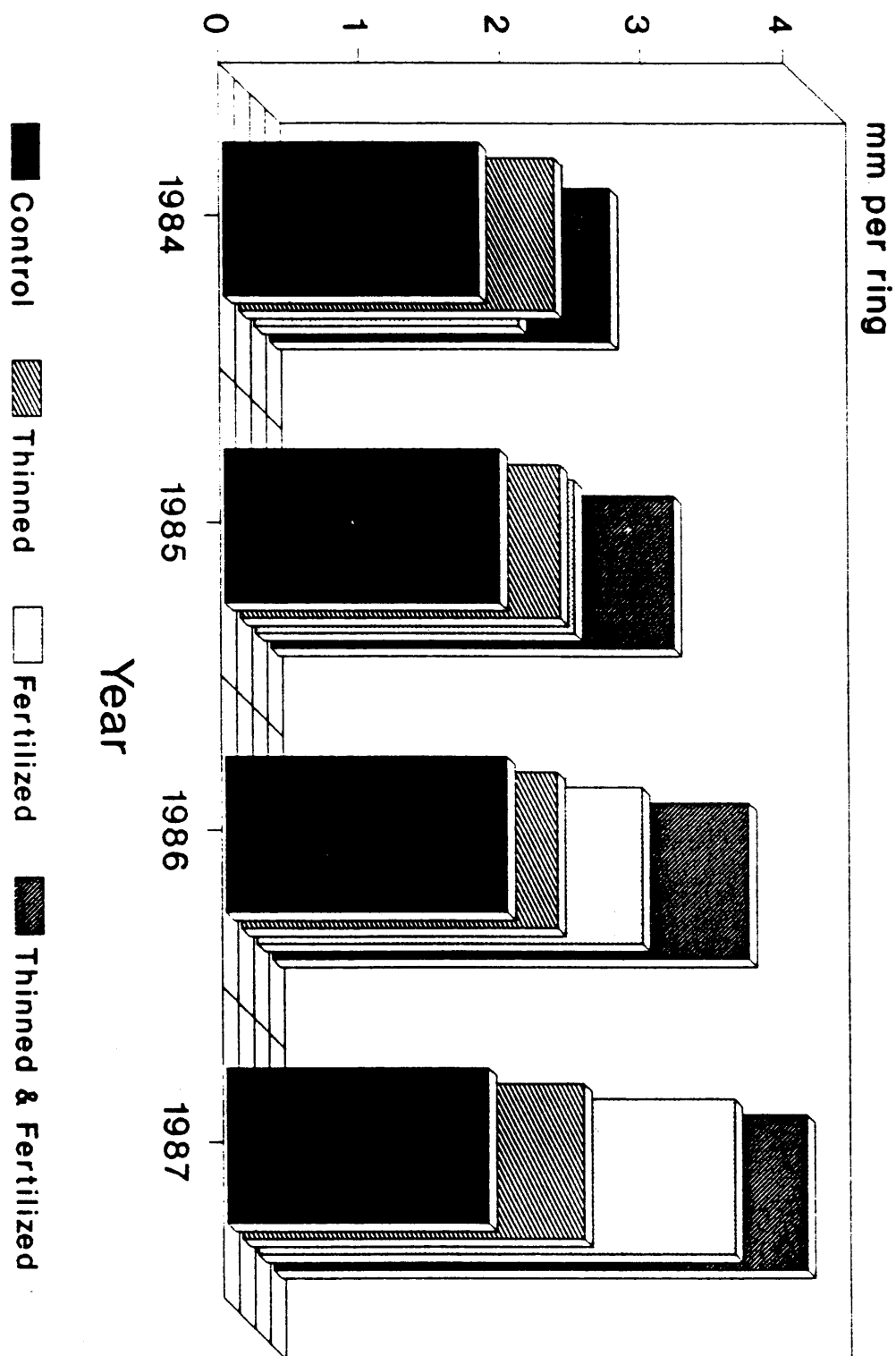


Figure 6

RADIAL INCREMENT



REGION 5'S PESTICIDE APPLICATION TRAINING - FY 1989 AND REGION 5'S IMPLEMENTATION STRATEGY FOR RESUMING THE USE OF HERBICIDES

David F. Thomas
Forest Silviculturist
Eldorado National Forest
and
Region 5 Pesticide Application Training Coordinator¹

ABSTRACT

The Regional Forester in Region 5 suspended the use of herbicides on National Forest lands as a result of a decision from the Ninth Circuit Court of Appeals in 1984. The Region has since been involved in a major effort to complete an adequate Environmental Impact Statement for Vegetation Management for Reforestation. On February 27, 1989, the Regional Forester issued a Record of Decision and Final Environmental Impact Statement for Vegetation Management to the public that allowed for the resumption of herbicides to control competing vegetation. Part of the Regional Forester's decision was that Region 5 personnel would be adequately trained in the safe and proper use of pesticides. In addition, the Regional Forester made pesticide training mandatory for any Region 5 personnel that would be involved in planning or implementing projects involving the use of pesticides. The Region assembled a training cadre of 41 instructors, and have since trained 225 Region 5 personnel in the safe and effective use of pesticides. Region 5 plans to have an ongoing pesticide training program to ensure that all Forest Service employees involved in pesticide application projects are adequately trained.

INTRODUCTION

As a result of a decision from the Ninth Circuit Court of Appeals in 1984, herbicide use has been suspended in California. The only pesticide projects that were being accomplished included gopher control, insect control and several nursery pesticides, such as soil fumigants. Herbicides were being utilized only in minor quantities, primarily as they were needed for small research projects, and they had to be approved by the Regional Forester on a case-by-case basis. Herbicide use in California has been a very sensitive issue with much of the public that we deal with in managing the National Forests. Once herbicide use resumes in California, the sensitivity with the public will significantly increase.

Region 5 issued the first Final Environmental Statement

for Forest Reestablishment on National Forests in California in 1974. In 1981, it became apparent that the 1974 document was becoming inadequate, due to new registration of new herbicides, new information on methods (such as new equipment and estimates of cost effectiveness), and increased public concern about methods used in vegetation management and their possible effects on the forest environment, the Region saw a need to prepare a new EIS. In August, 1983, the Region issued a Draft Environmental Impact Statement for Vegetation Management for Reforestation to the public. On February 27, 1989, The Regional Forester issued a Record of Decision and Final Environmental Impact Statement for Vegetation Management to the public, that allowed for the resumption of herbicides to control competing vegetation. To date, the Region has received 28 appeals on the documents.

Part of the Regional Forester's decision was that Region 5 personnel would be adequately trained in the safe and effective use of pesticides. In addition, the Regional Forester made pesticide training mandatory for any Region 5 personnel that would be involved in planning or implementing projects involving the use of pesticides. In anticipation to the Final Environmental Impact Statement, Region 5 began planning for pesticide application training in 1986, as Region 5 personnel were rapidly losing current pesticide experience. Most personnel in Region 5 have not been involved in pesticide application projects since 1983, a gap of almost 6 years. Due to the expected sensitivity of potential herbicide use, the Region developed a comprehensive plan to train approximately 200 to 300 Forest Service employees in the proper, effective and safe use of pesticides in Fiscal Year 1989.

In 1986, the Region established an original training cadre of 15 Forest Service personnel that had fairly extensive previous pesticide experience, and sent the cadre to the National Pesticide Application Training held in Marana, Arizona. The Region also established a back-up cadre of 13 individuals, who attended the 1989

¹ Presented at the 1989 National Silviculture Workshop, Petersburg, Alaska, July 10-13, 1989.

National Advanced Pesticide Management Training in Marana.

Three separate one week intensive, formal classroom sessions were planned for early 1989. The sessions were scheduled for Placerville, March 13-17, 1989, Sonora, April 10-14, 1989, and Redding, April 24-28, 1989. A comprehensive training agenda was developed (see Attachment Number 1), faculty assignments were made, and detailed lesson plans were written.

Three primary course objectives were established. They were:

1. To achieve journey-level knowledge for planning, preparing, implementing and administering pesticide-use projects.
2. Promote professionalism to ensure effective risk management and effective pest control programs.
3. Establish a network between field personnel and pest control expertise from both public and private agencies.

A comprehensive one week long field exercise was also scheduled for May 8-12, 1989 (see Attachment Number 2) at Growers Air Service, Woodland, California. The objective of the field exercise was to provide the students with hands-on experience with all techniques for pesticide application, including all forms of ground application, hand application and aerial application, for both helicopter and fixed wing aircraft.

A total of \$22,000 was budgeted to accomplish the Region's pesticide application training. Travel, per diem and wages for the cadre was not included in the \$22,000, but just the cost of course materials and the contract for aircraft at the field exercise.

TRAINING MATERIALS

A comprehensive course binder was published and contained all of the faculty course outlines, and detailed supporting handouts. The printed course binder totaled 675 pages. In addition to the course binder, a smaller binder was published with copies of all the currently available labels for registered forestry herbicides, as well as current Material Safety Data Sheets. Lastly, a copy of a recent publication from the University of California titled "The Safe and Effective Use of Pesticides", Publication 3324, was purchased for each student. Three hundred copies of all the course materials were printed or purchased (see Attachment Number 3 for a detailed cost breakdown for the entire course).

ACCOMPLISHMENT

All three formal classroom sessions were held as originally scheduled, as was the field exercise. The total attendance was 225 students from throughout the Region. The training cadre grew to a total of 41 instructors. The instructors came from a wide variety of backgrounds, from Forest Service instructors, representatives from the chemical industry, instructors from State and local governments, instructors from private industry, and instructors from the University of California, Davis. Each student received a "Certificate of Completion" specifically designed for this course signed by the Regional Forester. In addition, each student received 57 hours of continuing education credits from the Society of American Foresters, as well as 48 hours of continuing education credits from the State Department of Food and Agriculture for Pest Control Advisors. The overall rating from the students for the entire course was "excellent". The total direct cost of the training was \$21,700.

REGION 5'S IMPLEMENTATION STRATEGIES FOR RESUMING HERBICIDE USE

Now that the Regional Forester has released the Record of Decision and Final Environmental Impact Statement of Vegetation Management for Reforestation, and that the Region has satisfied his mandatory pesticide training requirement, plans are being developed to implement pesticide-use projects in FY 1990. All of the National Forests in Region 5 were asked to submit proposals that were specific to implementing the newly established Regional policy on herbicide-use. Three National Forests were selected to be pilot Forests. The Eldorado, Stanislaus and San Bernardino National Forest's were selected to develop specific project implementation plans, along with the appropriate NEPA documentation which would be utilized as "models" for the remainder of the Region, to implement herbicide projects in 1990.

Lastly, Region 5 successfully implemented a large pesticide-use project on the Lassen and Plumas National Forest's. The project involved the aerial application of *Bacillus thuringiensis* (Bt) to control a widespread outbreak of the Douglas-fir tussock moth. The suppression project successfully treated 83,871 acres at a cost of much less than the \$1.65 MM budgeted, without any accidents or major incidents. The project involved the use of eight Turbine Air Tractors, and six support turbine helicopters, plus approximately 80 ground support personnel. Most all of the Forest Service employees involved in the project had attended the Region 5 Pesticide Application Training, which contributed to the overall significant success of the suppression project.

ATTACHMENT NUMBER 1

R-5 PESTICIDE TRAINING - F.Y. 1989

DAY: *Monday*

0900 - 1200	Travel - Check in
1230	Dave Thomas - Introduction, Scope and Objectives Ray Weinmann - ARF, Timber Management, Regional Forester's expectations
1300	Project Planning Environmental Documents - Mike Srago - RO, TM Debbie Stefan - RO, P&B
1500	Public Information/Education - Frank Mosbacher, Eldorado PAO
1600	Laws and Regulations - Country Agricultural Commissioner
1630	Dave Thomas - Questions concerning chemicals - What do the students want to know? What works, how and when? Also, summarize Placerville.
1700	Adjourn

R-5 PESTICIDE TRAINING - F.Y. 1989

DAY: *Tuesday*

0800	Chemicals - What works, where and when? DuPont, Dow, Monsanto, Wilbur-Ellis, et. al. Moderator: John Roncoroni - U.C. Extension
1000	Summary: Moderator
1030	Break
1100	Application Technology - Jack barry, FPM - Davis
1200	Lunch
1300	Transportation, Storage and Disposal - Pieter Crosby - California Department of Health Services
1400	Pesticide Spill Plan - Bob Doty
1430	Break
1500	Small Tree Model - Modeling Vegetation Competition Larry Ticknor, PSW
1530	Economic Analysis - Mike SKinner, RO, P&B
1600	Hazardous Materials - Bob Bader, Stanislaus NF
1630	Adjourn
1900	Optional - Group Meeting - Scenarios

R-5 PESTICIDE TRAINING - F.Y. 1989

DAY: *Wednesday*

0800	Environmental Mitigation - Mike Ruty
0900	Pesticide Safety - Roy Rutz, California Department of Food and Agriculture
1000	Break
1030	Law Enforcement Planning - John Ruff, LE, RO
1100	Project Organization and Implementation Contract Preparation and Chemical Purchases Dave Allasia, RO, Contracting Officer
1200	Lunch
1300	Contract Administration - Ralph Phipps
1400	Project Personnel and Organization - Mike Ruty
1430	Aerial Equipment - Dave Thomas
1500	Calibration and Characterization - Aerial - Jack Barry, FPM, Davis
1700	Adjourn
1900	Optional - Group Meetings - Scenarios

R-5 PESTICIDE TRAINING - F.Y. 1989

DAY: *Thursday*

0800	Written Recommendations and Pesticide Prescriptions - Tom Simonson
0900	Project Monitoring - Bob Rogers
1000	Break
1030	Project Documentation - George Lottritz Project Evaluation and Monitoring - Bob Rogers
1100	Personal Protective Clothing and Equipment - Joe Mack, International Reforestation
1200	Lunch
1300	Actual Case Study - Plumas NF Douglas-Fir Tussock Moth Suppression Experiment - 5,266 Acres, Ron O'Hanlon Video Tape - 15 minutes
1400	Students Finalize Presentations on Scenarios (Break into groups)
1500	Group Presentation on Solution to Each Scenario Group Discussion Instructor's Solution
1600	Introduction to Field Exercise, Aircraft Safety - Dave Thomas a. Aircraft Safety Plan b. MSDS for FDS #40 Dye c. Micronair AU5000 Rotary Atomizer, on-board flow meter d. Kromekote cards for characterization trials, handlens
1700	Adjourn

R-5 PESTICIDE TRAINING - F.Y. 1989

DAY: *Friday*

0800	Ground Application - From Start to Finish John Ford, Pesticide Applicator's Professional Association
1200	Course Wrap-up, Critique - Dave Thomas, John Neisess

ATTACHMENT NUMBER 2

R-5 PESTICIDE TRAINING - F.Y. 1989

FINAL AGENDA

DAY: *Monday*, May 8 Growers Air Service, Woodland, California

0800-1200 Travel - Check in

1230 Session #1
Arrive - Growers Air Service
Introduction/Safety - Dave Thomas
 (All of Group)

1300 Mixing/Loading - Growers Air Service, Group #1
 (1/3 of Group)
Introduction to Aircraft - Fixed Wing, Growers Group #2
 (1/3 of Group)

1400 Introduction to Aircraft - Helicopters, Growers Group #3
 (1/3 of Group)

1430 Calibration - Fixed Wing - Group #1

1530 Calibration - Helicopter - Group #2

1630 Introduction to Characterization - Jack Barry, Dave Thomas

R-5 PESTICIDE TRAINING - F.Y. 1989

DAY: *Tuesday*, May 9 Growers Air Service, Woodland, California

0500	Characterization Fixed Wing Helicopter
0900	Group #1 - Wilbur-Ellis - Scott Johnson
1000	Group #2 - Monsanto - Dan Coombes
1100	Group #3 - Dow Chemical - Vanelle Carriethers
1200	Lunch
1300	Group #4 - Dupont - Larry Ballew, Frank Aulgur
1400	Group #5 - Ground Application - Backpack Sprayers - Stewart Craig, Butch Geyer
1500	Group #6 - Ground Application Equipment - Farm Tech, Inc. - Doug Dubey
1600	Group #7 - Nozzeles - Spraying Systems and Delavon - Allan Dyer, Kisco Sales, Inc.

R-5 PESTICIDE TRAINING - F.Y. 1989

DAY: *Wednesday*, May 10 Growers Air Service, Woodland, California

0800	Group #8 - Aerial Application - Simplex Manufacturing
0900	Group #9 - Tractor Mounted Spray System - U.C. Davis Agricultural Engineering Department
1000	Group #10 - Hack and Squirt, Tree Injection, Stump Treatment
1100	Adjourn
1230	Session #2 Arrive - Growers Air Service Introduction/Safety - Dave Thomas (All of Group)
1300	Mixing/Loading - Growers Air Service, Group #1 (1/3 of Group) Introduction to Aircraft - Fixed Wing, Growers Group #2 (1/3 of Group)
1400	Introduction to Aircraft - Helicopters, Growers Group #3 (1/3 of Group)
1430	Calibration - Fixed Wing - Group #1
1530	Calibration - Helicopter - Group #2
1630	Introduction to Characterization - Jack Barry, Dave Thomas

R-5 PESTICIDE TRAINING - F.Y. 1989

DAY: *Thursday*, May 11 Growers Air Service, Woodland, California

0500	Characterization Fixed Wing Helicopter
0900	Group #1 - Wilbur-Ellis - Scott Johnson
1000	Group #2 - Monsanto - Dan Coombes
1100	Group #3 - Dow Chemical - Vanelle Carriethers
1200	Lunch
1300	Group #4 - Dupont - Larry Ballew, Frank Aulgur
1400	Group #5 - Ground Application - Backpack Sprayers - Stewart Craig, Butch Geyer
1500	Group #6 - Ground Application Equipment - Farm Tech, Inc. - Doug Dubey
1600	Group #7 - Nozzeles - Spraying Systems Inc. - Doug Snyder

R-5 PESTICIDE TRAINING - F.Y. 1989

DAY: *Friday*, May 12 Growers Air Service, Woodland, California

0800 Group #8 - Aerial Application - Simplex Manufacturing

0900 Group #9 - Tractor Mounted Spray System -
U.C. Davis Agricultural Engineering Department

1000 Group #10 - Hack and Squirt, Tree Injection, Stump Treatment

1100 Adjourn

ATTACHMENT NUMBER 3

ESTIMATED EXPENDITURES TO DATE - R-5 PESTICIDE TRAINING
May 18, 1989

1. Kromocote cards (Jack Barry)	\$1,128.86
2. Placerville Inn (cadre meeting)	\$50.00
3. Publication 3324 - The Safe and Effective Use of Pesticides	\$5,400.00
4. Contract for Aircraft - Growers Air Service	\$5,000.00
5. Wilbur-Ellis	\$120.00
6. Ear plugs	\$20.48
7. Red dye - FDC #40	\$362.50
8. Disposable coveralls	\$692.00
9. Graphics (covers for binders, course certificates, etc.)	\$276.05
10. Placerville Inn - Rental of classroom	\$250.00
11. Per diem - Thomas	
a. Sonora	\$301.02
b. Redding	\$95.64
c. Redding	\$391.50
d. Davis	\$386.08
12. Course binders @ 600 copies	\$1,850.00
13. Kisco Spraying Systems	\$389.10
14. Printing - Course Binder	\$2,728.30
15. Wages - Office Services -Build binders [est.]	\$500.00
16. Solo backpack sprayers	\$221.63
17. Sonora - Room rental/VCR	\$450.00
18. Granular herbicide spreader	\$207.00
19. Hypo-hatchet/tree injector	\$245.00
20. Per diem - John Roncoroni, UC Davis	\$220.04
21. Per diem - Roy Rutz, CDEA	\$275.80
22. Kisco - #8006 nozzles	\$67.20

Sub-total	\$21,628.20
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The total budget for the R-5 Pesticide Application Training was \$22,000.

Dave Thomas
Eldorado National Forest
R-5 Pesticide Application Training Coordinator

SILVICULTURAL RESEARCH FOR MULTIPLE RESOURCE MANAGEMENT OF ASPEN IN THE CENTRAL ROCKY MOUNTAINS

Wayne D. Shepperd
Silviculturist

Rocky Mountain Forest and Range Experiment Station
Ft. Collins, CO¹

Abstract

Demand and concern for the aspen resource in the Central Rocky Mountains have intensified during the past 15 years. The need for alternate silvicultural strategies to meet multiple resource objectives in aspen stands has required a concurrent silvicultural research effort. Several silvicultural studies and their management applications are discussed.

Introduction

Intensive management practices for aspen forests in the Central and Southern Rocky Mountains are of relatively recent vintage. Historically, low demand for aspen wood products resulted in little interest in management or silvicultural research. Prior to 1976, aspen accounted for only 2% of the annual timber harvest in the Rocky Mountain Region (Mathison, 1976), even though aspen occupies about a third of the forested area in Colorado alone. A concern was growing, however, many aspen forests were reaching maturity and would soon be replaced by conifers at the expense of wildlife habitat and scenic vistas.

In 1983, the aspen management picture quickly changed when Louisiana Pacific announced construction of two waferwood mills in Colorado that would utilize aspen. This market for aspen provided a means to effectively and economically manage a much greater portion of the aspen resource.

However, managers were not fully prepared for such a sudden turn of events. The waferwood mills had not begun operation before a controversy arose over the planning process and management guidelines used by the Forest Service to select aspen stands for harvest, since many stands were not classified as commercial forest land. The intensification of aspen management in

the Rockies had created a need for additional research to establish silvicultural techniques to manage aspen for a variety of resource uses.

Silviculture Research in Aspen at the Rocky Mountain Station

The aspen silvicultural research program at the Rocky Mountain Forest and Range Experiment Station was initiated by John Jones when he published site index curves for aspen and a series of ecological and regeneration studies (Jones 1966, 1971, 1974, 1976; Jones and Trujillo 1975a, 1975b). This material served as the basis for the first draft of a book later revised and published as General Technical Report RM-119 "Aspen Ecology and Management in the West" (DeByle and Winokur 1985).²

Recent aspen growth and yield research has included the development of volume tables (Edminster et. al. 1981, Shepperd and Mowrer 1984), site index curves (Edminster et. al. 1985), an aspen module for the RMYLD stand growth model (Edminster and Mowrer 1985), and a normal diameter distribution growth and yield model (Mowrer, 1986a). We have also produced equations for estimating bark thickness and past diameters (Mowrer and Edminster 1985), mean annual volume productivity (Mowrer 1986b), and leaf areas (Kaufmann et. al. 1982).

Our current research emphasizes not only aspen stands that have the potential for commercial management, but those managed for other purposes as well. This program was developed in response to the need for more information about how the large aspen resource in the Rockies should be managed. Results available to date have been incorporated in management guidelines for aspen in the Rocky Mountain Region (U.S. Department of Agriculture 1985).

¹ Presented at the 1989 National Silviculture Workshop, Petersburg, Alaska, July 10-13, 1989.

² GTR RM-119 Also summarizes the numerous contributions of the research work unit entirely devoted to aspen, which was maintained by the Intermountain Station from the early 1970's until 1985. Work done by this work unit greatly expanded our knowledge of the physiology, regeneration, ecology, and wildlife habitat relationships of western aspen.

The Aspen Stand Classification Study

The Aspen Stand Classification Study (Shepperd 1981) has been underway since 1979. This study was undertaken to meet two objectives: 1. Describe the range of aspen stand and growth conditions in the Central and Southern Rockies. 2. Develop a classification system based on information available from Stage II inventory that would be helpful in making management decisions in Rocky Mountain aspen forests. Growth, site, and clonal characteristics from 140 aspen stands throughout Colorado and southern Wyoming were compared. A number of trends were noted:

1. Most aspen in the Rockies is mature, from 60 to 120 years old. Younger stands are rare, but occasional old-growth (120-180 years) stands can be found.
2. Not all aspen is even-aged. About 20% of the stands encountered were two-, or multi-aged.
3. Aspen grows on a variety of sites in association with both montane and subalpine vegetation.
4. Growth characteristics expressed on a clonal basis can be useful in identifying stand condition. For instance, height of live branches can be used to identify the relative age of a stand, and yellowish bark color may be indicative of stress.

A cluster analysis was used to incorporate these and other relationships into a classification scheme based on stems per acre, average stand age, average stand height, and site index. These characteristics are used to assign stands into one of seven management classes that require different silvicultural or management considerations. Briefly, these classes are:

1. Mature, average stocking and productivity. Capable of commercial management.
2. Middle-aged, poorly stocked, low productivity. Commonly occur on dry sites. May be hard to regenerate.
3. Young, dense, fast-growing sapling stands without measurable commercial volumes.
4. Young, moderately stocked, sapling stands with measurable commercial volume.
5. Mature, heavily stocked, highly productive stands. Highly suited for sustained fiber production.

6. Middle-aged, healthy, well-stocked stands with high production. Management can be deferred in these stands.
7. Very old, well-stocked stands that provide valuable wildlife habitat and aesthetic appeal.

An interactive expert system computer program is being developed that will assign any inventoried aspen stand to one of these classes and provide users with a description of the selected stand type and a narrative of suggested management alternatives. The program will enable local managers to quickly gain an understanding of how aspen stands in their area compare to those elsewhere in the Rockies, and to identify stands that may require special silvicultural consideration.

Alternative Silvicultural Practices

Not all aspen in the Rocky Mountain Region is of commercial quality, or located near viable markets. Yet many non-marketable stands need to be regenerated for scenic, watershed, or wildlife purposes. For such situations we have compared bulldozer pushing and chainsaw felling to remove the aspen overstory and stimulate suckering. The effects of fencing to exclude domestic livestock, and leaving the overstory slash on site were also investigated in this replicated split-block study.

Although sucker regeneration was quite variable, several conclusions were reached. After five growing seasons, dozer-pushed areas contained more suckers than those cleared by chainsaw felling. Removing the stumps apparently stimulated the remaining lateral roots to sucker more vigorously. Fenced areas contained more suckers than unfenced areas, regardless of the regeneration technique used. Leaving slash in place offered some protection from animals, but did not allow as many suckers to become established and therefore was generally detrimental.

Bulldozer pushing, if properly applied, can be a successful regeneration technique in Rocky Mountain aspen. However, the large variation in sucker counts between replications in this study indicates that site and clonal differences can affect aspen regeneration success, regardless of the technique used.

Managers in the Rocky Mountain Region who are planning silvicultural treatments in aspen often inquire about the possibility of using partial cutting to regenerate some clones, especially where scenic values, or thermal and hiding cover for wildlife, are a concern. Although some

clones have suckered following old partial cuts or natural mortality of a portion of the overstory, but no quantitative data existed documenting an attempt to regenerate using partial cutting.

In 1981 we installed a study in a 70-year-old aspen stand on the Fraser Experimental Forest to investigate the effect of a simulated commercial thinning in pole-sized mid-aged aspen. The thinning removed 0%, 25%, 50%, 75%, and 100% of the original basal area. All large ungulates were fenced from half of each thinning treatment to document any effect of browsing. Suckering response was then monitored on permanent regeneration plots measured yearly. Only the 75% and 100% removal treatments stimulated appreciable suckering. Survival has been poor, even in the clearcut and fenced area.

Growth increased due to thinning, but mortality caused directly or indirectly by the thinning activity offset much of this gain. Our conclusion was that partial cutting did not adequately regenerate the stand, even with protection from browsing animals, and that the commercial thinning was impractical.

The above study was in an older stand. However, could aspen benefit from a pre-commercial thinning at young ages where stems could be removed without damage to residual stems and regeneration is not a concern? Although aspen normally self thins, there are situations where a pre-commercial thinning might be justified. Some clones sucker so profusely that livestock cannot access forage beneath them for many years. In other cases, it may be desirable to remove stems of poor form to enhance future product quality.

To answer these questions, we have initiated a long-term pre-commercial thinning study in young aspen stands on the Routt, Gunnison, and Uncompahgre National Forests. This study will also provide growth information for yield model updates. No post-treatment data have been collected, but growth increases and new suckering are evident in two areas. Heavy snow has damaged residual stems in thinned treatments at the third study site. This damage, and the extreme effort required to thin stands containing tens of thousands of stems, are factors managers should consider before thinning young aspen in the Rockies.

Experience with these studies and data from the Routt and San Juan National Forests published by Crouch (1981, 1983, 1986) indicate that not all aspen stands regenerate well following clearcutting. This prompted us to complete a region-wide survey of 32 regenerated aspen

stands in 1985 that had been clearcut at least 5 years previously. Stocking, internal and external damage, and disease were all assessed.

Most aspen suckers were found to have some type of damage or defect. The effects of damage on sucker vigor appear to be additive. With the exception of disease outbreaks, stands appear to successfully regenerate where initial suckering is prolific and suckers are not damaged repeatedly, or by multiple agents.

Aspen Root System Dynamics

Another aspect of our research is geared toward gaining more knowledge of the basic physiologic and ecologic relationships in the life cycle of aspen. Aspen in the Rockies is dependent upon its lateral root system to regenerate. To better understand what is driving this process, we are studying root system development under various stand conditions, and the changes that occur in roots after a stand is harvested.

We also are studying how the harvesting practices themselves affect lateral root system development. Poor sucker stocking on skid trails and landings in some areas prompted us to determine the increase in soil density resulting from skidding vehicles and its effect upon aspen roots. We have found that compaction does occur, and that wet soils can increase damage to aspen roots. We will soon be testing existing clearcut sites to determine how long compaction effects persist.

Future Research Needs

Although we have gained a better understanding of the management of aspen in the Rocky Mountains, many unanswered questions remain. More aspen is now being harvested annually in the Rockies than ever before. Aspen's scenic, wildlife, and watershed values remain critical as the majority of the aspen resource continues to age. Additional silviculture research is also needed in mixed aspen-conifer stands. These stands offer a great deal of diversity, and provide quality habitat for many wildlife species. Such stands have traditionally been considered seral to conifers, but some may have existed in a mixed overstory mode for some time. Understanding the dynamics of these stands could lead to the development of cultural practices to either maintain, or establish, a mixed species condition. Such techniques would not only benefit wildlife, but visual, timber, and watershed resources as well.

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A BROADER VIEW OF FOREST ECOLOGY

W. J. Hann

Group Leader for Ecosystem Management
Northern Region USDA Forest Service
Missoula, Montana¹

ABSTRACT

The typical perspective of forest ecology is usually limited to classification of site potential and the study of vegetation response to succession. This perspective limits the application of ecological information to individual sites and the changes that occur over time. There is a growing awareness that spatial relationships of ecological systems may be as important for application in management systems, as site and succession concepts. This paper provides an overview of a strategy for analyzing ecosystems from the aspects of diversity and landscapes. Suggestions are also made for incorporation of a new philosophy into the "art and science" of silviculture for the 1990s.

INTRODUCTION

The perspective of most silviculturalists and ecologists of forest ecology has historically been limited to the stand or community level. Our measurements, management treatments, and monitoring has focused on relatively small areas, such as the stand, community, macroplot, or even microplot level. However, when we step back and view our forest ecosystems from a landscape level a much broader view of forest ecology becomes apparent. This is the emerging science of "landscape ecology," which involves not only the study of the mosaic of communities and stands across the landscape, but the interaction and connections of genes, populations, species, and communities.

This is a perspective that requires us to think "big" and to emphasize relationships and connections rather than internal dynamics. It places an equal importance on understanding the effects of macro-geographic effects, such as pollution, changing climate, insect and disease epidemics, spread of exotic species, and large fires, with their relationship to smaller scale effects, such as community response, species conservation, and individual stand treatments.

An understanding of landscape ecology is tiered within the science of diversity ecology, which involves understanding the physical, chemical, and biological diversity of natural systems and evaluating the effects of man on diversity. Man's survival is dependent on the conservation of the diversity of natural physical, chemical, and biological processes. The diversity of biological species and associated genes is critical for development of improved agricultural food and fiber, and for the biomedical industry. The loss of any species or genetic diversity of a species is a loss to the present and future array of tools we can use for the "care and feeding" of mankind. Conservation of physical and chemical processes and components not only conserves important substances for man's use, but provides habitat for the diversity of biological species, populations, and communities.

A quote from Aldo Leopold is appropriate relative to the discussion of landscape ecology and biodiversity. "If the land mechanism as a whole is good, then every part is good, whether we understand it or not. To keep every cog and wheel is the first precaution of intelligent thinking."

Various definitions have been presented for the "art and science" of silviculture. I prefer definitions that broaden the perspective of silviculture to include the management of forests for production of resources, while maintaining ecologically productive and functional ecosystems across time and space. This paper provides a brief overview of the concepts of this broader view of forest ecology and silviculture, and recommends a different approach for silviculturalists in the 1990s.

DIVERSITY AND CHANGE ACROSS TIME

Ecologists and silviculturists that observe and study the change of forest communities over time, soon realize that there is a wide diversity of vegetation response to different effects, which results in more than one successional sequence of communities. Egler (1954) and Miles (1979) discuss the concepts of multiple path succession,

¹ Presented at the 1989 National Silviculture Workshop, Petersburg, Alaska, July 10-13, 1989.

which is the rule in forest ecosystems, rather than the single path sequence, often discussed in classrooms or textbooks. The diversity of successional sequences has been adequately demonstrated by many studies in North America. Results from some studies have been presented for the northern Rocky Mountains by Arno, Simmerman, and Keane (1985), Keane (1987), Hann (1982), and Steele (1985).

The basis for the multiple path succession concept is that, for any given vegetation community, on a given type of site, a different successional sequence will result for each different treatment or disturbance, and combination of available plant species. Different combinations of harvest systems combined with different types of site preparation, usually result in different vegetation responses and successional pathways. In natural systems fire, insects and disease, wind, cold damage, animals, snow avalanche, soil mass failures, and other factors of disturbance combine to create a wide diversity of vegetation responses and secondary successional pathways. The presence of seed source, vegetative resprouting, other survival mechanisms is also a key factor in variations of vegetation response and succession. Intermediate treatments or disturbances along the successional pathway can shift the sequence of communities.

Certain successional sequences are predisposed to having a given type of disturbance at cyclic intervals, that coincide with the development of a susceptible type of community. A common example of this type of system, is development of lodgepole pine dominated communities, on certain types of sites, following fire. These communities are relatively resistant to mountain pine beetle while the lodgepole pine is young and vigorous. During these early seral stages the communities also have relatively low accumulations of fuel and have low potential for fire intensity and spread. However, as the lodgepole and other vegetation of the community matures, the lodgepole becomes susceptible to the mountain pine beetle and fuels begin to accumulate. Once the dead lodgepole start to fall and the community develops a continuous network of both fine and large fuels, it is highly susceptible to rapid fire spread and high intensity fire, given an ignition. Since lodgepole on these types of sites usually has serotinous cones, that release seed after heat treatment, the cycle of lodgepole regeneration is continued. It is important to emphasize that this pattern is not the case on all sites where lodgepole dominated communities exist. Also, different types of sites respond differently, relative to the species that are associated with lodgepole and the growth rates through the successional sequence.

Another example of the natural cycle of disturbance and successional sequence, that is on a much shorter

cycle, involves ponderosa pine and Douglas-fir. In natural systems on dry, usually south facing slopes, in the northern Rocky Mountains, these two species, alone or mixed, often dominate park-like communities. Fire occurs fairly frequently in these systems; often as frequent as every 5 to 15 years. The large dominant trees have thick bark that protects the tree from damage by understory ground fire. Often these large trees have fire scars at the base that can be measured to reconstruct the fire history (Arno and Sneek 1977; Arno 1980). Since fires are fairly frequent, fuel accumulations are relatively low and consist primarily of dry grass and litter. As years pass without fire, the dry grass and litter accumulate, increasing the probability that these communities will burn if an ignition occurs. When the community does burn, the grass and litter burns as an understory ground fire, also consuming shrub and tree regeneration, thus maintaining an open park-like community. Extensive grazing and fire suppression have essentially eliminated this natural cycle and these types of communities by reducing fine grass fuels and fire ignitions. Once several of these cycles have been missed, a fuel ladder of shrubs and sapling to pole size trees develop, along with heavy ground fuels, that will carry a fire into the large overstory trees. Most of these types of communities are now at this stage and are outside their natural successional cycle. Fires that occur in these communities during the typical hot, dry, windy summer fire season, will crown and kill the large overstory trees. Prescribed fire, ignited during cooler weather conditions, with a narrow range of wind and fuel moistures, can be used to reduce the fuel ladder and bring the communities back in to their natural vegetation and fuel cycle.

These examples are just two of many different successional sequences and cycles that can occur. Figure 1 is a schematic showing different successional pathways that coincide with typical seral stages of structural development. The schematic represents successional pathways and communities for one type of site. Each path results from a different combination of treatments or disturbance. Certain communities, such as those resulting from frequent fire, extreme competition, or disease, may be maintained as a relatively stable community or cycle. Some successional pathways may develop at a fairly rapid rate, while others may be very slow, often appearing to be stagnated. In general as successional stages advance, there are less possibilities for different community types (CTs), since there are less species available that can dominate these structural stages.

It is important to understand the different pathways that can result from different management treatments, and also those that occur in relation to natural cycles of disturbance. This understanding is important not only from the aspect of maintaining a diversity of commu-

nities and processes, but also in developing a range of management treatments, that produce the best mix of resources in a sustainable manner. Many treatments are viable in the short-term, but do not provide for maintenance of desirable sequences or cycles of communities. It may be much more efficient to select a treatment that provides a more desirable successional pathway through the full length of successional development.

DIVERSITY AND CHANGE ACROSS SPACE

When we step back and view landscapes it is readily apparent that no two landscapes are the same. However, natural landscapes are often relatively similar within the same geoclimatic area. A geoclimatic area has similar parent materials, landforming processes, and climate, such that the landforms and climatic patterns, and the resulting zonation of biotic communities, are fairly similar within the area. Within a geoclimatic area the zonation of potential (climax) communities across elevation gradients is relatively consistent. The mosaic of various communities and structural stages, and size and shape of communities, is commonly somewhat similar from one watershed to the next within a geoclimatic area. When evaluating similarity of landscapes across different areas, the factor of time cycles must also be taken into account. Large scale events, such as stand consuming fires, often produce a cycle of landscape mosaic and communities that is similar from one watershed to another. However, because the adjacent watersheds are in different stages of this cycle, they may not appear to have similar landscape mosaics and communities at a given point in time. If both watersheds can be compared at the same stage of development following the large scale event, the landscape mosaic and communities would be very similar.

There are a wide array of factors that control and create variety in landscape mosaics. In mountainous terrain, variation in site factors of landform, elevation, aspect, parent material, soils, and proximity to water, usually control the landscape mosaic in terms of site potential and sizes and shapes of communities. Factors of disturbance, and time since disturbance, control the kind of communities that occur within the successional pathways available for a given site potential.

Landscape ecology is an emerging science and much of what is presently happening in this field is research. However, it is time for managers to start considering landscapes not only in the inventory phase, but in the development of groups of stand treatments, road location and access, and in designing community shapes, sizes, and patterns. One has only take a brief glance at a watershed that has had man's historic cutting and road activities, and compare that to an adjacent watershed

that has had more natural disturbance, to conclude that man has created landscapes, which differ significantly from natural landscapes. In typical managed watersheds natural boundaries are often not followed, patterns are regular and systematic rather than random, roads create major boundaries that disrupt animal travel patterns and produce sediment delivery systems, community boundaries are straight instead of curved or irregular, community shapes are square or rectangular rather than oval or irregular, and community size has little variation compared to a wide range of sizes in the natural landscape.

Except for the negative effects from roads, some managers question that the natural landscape and mix of communities and species, is correct for ecological stability and production of resource products. This may well be the case. However, the plants and animals of these ecosystems have evolved over millions of years with the natural landscape mosaic and processes. Until we better understand ecological stability and relationships between mixes of different ecosystem attributes, it seems logical to follow Leopold's advice and "keep every cog and wheel." Certainly from an aesthetic point of view, a watershed that is managed to provide a mosaic similar to that which naturally occurs, is much more acceptable.

Much of the landscape has had considerable historic alteration by man and it is difficult to establish a baseline for the natural landscape and mix of communities. Many landscapes that appear natural are actually not, due to the influence of the past 40 to 60 years of fire suppression. There are tools available that can help establish a baseline for natural landscapes. These include use of old aerial or oblique photographs, analysis of fire scarred trees, and use of models to evaluate sequences of landscape change with typical disturbance and succession regimes. Large Wilderness and semi-primitive management areas, where fire has been allowed to play a relatively natural role, provide an actual outdoor laboratory for these types of assessments.

An important concept has emerged relative to present day harvest patterns and sizes. This is the concept of "fragmentation." This concept is well presented by Franklin and Forman (1987) in an assessment of cutting patterns in the western Cascade Mountains. Similar effects appear to be consistent for historic cutting patterns in the northern Rocky Mountains.

The concept of fragmentation is presented briefly in the following discussion. Figure 2 presents a simplified version of a natural landscape with 2 communities in a 300 acre area. Each community is approximately 150 acres in size and irregular in shape. There is one ecotone that connects the two communities. Figure 3 shows the

effect of 1 harvest unit that is 10% of the area, or 30 acres in size. The average size of the remaining uncut communities is 135 acres, ranging from 120 to 150 acres. Three communities have been created with two ecotones to connect the three communities. Figure 4 shows the effect of two harvest units that make up 10% of the area, with an average of 15 acres each. The average size of the remaining uncut communities is 135 acres, with no range in variability. Figure 5 shows the effect of 6 harvest units that make up 10% of the area, with an average of 5 acres each. The uncut community size still averages 135 acres, but each is nearly divided into 3 or 4 fragmented communities. There are 7 ecotones that connect communities. With only a small amount of additional cutting, the two original communities would be completely fragmented.

Permanent roads also fragment landscapes, break up travel corridors, create unnatural ecotones, and create a path for spread of exotic plants and animals. Deep road cuts change hydrologic subsurface flow, increase the chances of mass failure, create unnatural drainage systems, and provide a sediment delivery system into water channels. Various methods can be used to reduce the impact of roads. These may range from constructing narrow roads with low cut slopes, which are closed during sensitive seasons, to temporary road systems that are constructed for harvest activities and then closed and rehabilitated until the next entry into the watershed.

It is important to emphasize that it is not the actual size or number of communities and ecotones that is of concern. It is the size, range in variability, shape, ecotone, and juxtaposition of different types of communities, relative to what is present in the natural landscape. In figure 2, if one of the communities is an overmature forest community, that has high susceptibility to fire, it may better fit the natural landscape to initiate a mix of harvest and prescribed fire treatments that would reflect a natural fire that crowns and underburns through an overmature forest stand. However, it is also important to emphasize that contrary to what some managers think; a clearcut does not replicate a stand consuming crown fire. Stand consuming crown fires usually leave standing snags and often underburn in small areas with light fuel loading or high moisture content. A mix of seed tree and shelterwood harvest units with an understory prescribed burn, and retention of the overstory, may better reflect the natural landscape and ecological processes.

RESOURCES IN THE CONTEXT OF MAN'S NEEDS

With all the emphasis on conserving resources, and natural communities and processes, it may seem that the ecological perspective is against timber harvest. This

is definitely not the case. Man must have wood products for shelter and other fiber needs. Certainly it is far better to produce products for shelter from a renewable resource, such as wood, rather than a nonrenewable resource, such as stone, brick, and steel. The removal of nonrenewable mineral and stone resources permanently alters the landscape and usually reduces the site potential, thus eliminating an opportunity for conservation of a natural landscape and its communities.

The emphasis should be on producing wood products in a sustainable manner, while providing ecologically stable systems. An understanding of the landscape mosaic and community processes will help managers implement harvest and access systems that are ecologically viable.

SUMMARY - SILVICULTURE IN THE 1990s

From a simplistic standpoint we can conclude that there are three key objectives when designing a silvicultural system to fit within the ecological system.

1. Protect basic values of soil, air, water, and biota.
2. Conserve natural boundaries, communities, and variability by mimicing natural processes at the community and landscape level.
3. Design management systems that produce forest resources, while providing for maintenance of long-term site productivity and maintaining natural diversity across time and space.

To meet the requirements of the National Environmental Policy Act (NEPA) silviculture should design alternatives and analyze effects in reference to the three basic objectives. Arguments based on biological information must be presented for those alternatives that are not ecologically viable, even though some publics may promote alternatives that are only positive relative to short-term aesthetics. The interdisciplinary team process should be one of integrated, site specific alternatives and analysis of effects, to select the best combination of treatments, rather than advocacy for or against a standard set of programmatic treatments and mitigations. NEPA documents should adequately describe alternatives and disclose effects so that the reader can aggregate or evaluate site specific effects to form their own opinion of the actions being proposed.

The present environmental movement and emphasis on biodiversity and other noncommodity resources should not be seen as a threat. Silviculture as a part of forestry should lead resource managers in providing strategies for long-term ecologically based systems, while producing

wood and other products. The goal should be to produce desirable forest environments to meet local and national objectives, within natural ecological cycles. I encourage you not to wait for another professional to be your conscience. If you know that an alternative is not ecologically viable and has negative consequences, then attempt to design an alternative that better fits the ecological system.

Silviculture as a profession needs to move forward to meet the challenges of the 1990's. With limited budgets the trend will be to reduce personnel unless their expertise is vital to implementation of agency goals. The expertise of silviculturists is a valuable asset in forest ecology and multiple-use resource management. In my opinion, the challenge of the 1990's to Silviculture, is to move time and expertise away from "getting out the cut" and other timber targets, and into management of ecological systems and education of internal and external publics.

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BIOLOGICAL DIVERSITY AND SILVICULTURAL SYSTEMS

Thomas R. Crow
Research Ecologist
North Central Forest Experiment Station,
Rhinelander, WI 54501¹

"The days have ended when the forest may be viewed only as trees and trees only as timber. The soil and water, the grasses and shrubs, the fish and the wildlife, and the beauty that is the forest must become integral parts of the resource manager's thinking and actions."

Hubert Humphrey - Congressional testimony for the National
Forest Management Act of 1976

INTRODUCTION

Biological diversity is an international issue that has profound implications for managing natural resources. At the root of this issue are concerns about the accelerating losses of species due to the cumulative impacts of human activities. While past as well as current rates of species extinctions are difficult to determine, biologists generally agree that we are currently experiencing losses of diversity that are without precedent in human history and that these losses are a significant problem relating to human welfare (Lovejoy 1986, Myers 1986, Wilson 1988). Increasingly, foresters will be asked to assess the impacts of their management practices on biological diversity. This is no small task – almost every forestry application affects biological diversity in some way.

Such requirements already apply to Forest Service planners and managers as part of the National Forest Management Act (NFMA) of 1976. The context for this legislation was concern about forest-type conversion, or more specifically, the large scale conversion of mixed hardwoods to pine plantations (Peterson 1984). The regulations developed as a result of this legislation reflect a desire to provide flexibility and to give professional foresters the discretion to meet a variety of situations in the field. There are no definitions of diversity within the regulations nor are there many specific standards that must be met. Instead, NFMA states that land managers on national forests must "...provide for diversity of plant and animal communities based on the suitability and capability of the specific land area in order to meet overall

multiple-use objectives, and within the multiple-use objectives of a land management plan adopted pursuant to this section, provide, where appropriate, to the degree practicable, for steps to be taken to preserve the diversity of tree species similar to that existing in the region controlled by the plan."

It is important, however, to distinguish between the legal requirements for maintaining diversity and the broader scientific concepts relating to diversity. Planners and managers in the Forest Service need to be "up-to-date" regarding these concepts and they need to be aware of their applications (or potential applications) to resource management. In the final analysis, however, "the problem of biological diversity" as viewed by resource managers may be less a "scientific problem" than it is a perceptual and attitudinal problem.

WHAT IS BIOLOGICAL DIVERSITY?

In its report on "Technologies to Maintain Biological Diversity," the Office of Technology Assessment, an arm of the U.S. Congress, described biological diversity as "...the variety and variability among living organisms and the ecological complexes in which they occur." Technical definitions such as this do little to increase our understanding of complex concepts. Instead, let us consider some characteristics of diversity to help us obtain a better grasp of the concept.

There are three types of diversity – compositional, structural, and functional – that are related but also repre-

¹ Presented at the 1989 National Silvicultural Workshop, Petersburg, Alaska, July 10-13, 1989.

sent logical subgroups (Fig. 1). Compositional diversity includes the commonly recognized species component of diversity as well as genetic and ecosystem diversity (Fig. 2). Maintaining genetic diversity is critical to maintaining species diversity, and maintaining critical ecosystems provides the necessary habitats for conserving diverse species. These three levels form a biological hierarchy that reflects their functional interdependency. Obviously, a comprehensive plan to conserve species diversity will require considering all three levels.

Structural diversity at the stand level can be characterized by the number of strata within the forest (e.g., canopy, subcanopy, shrubs, herbaceous plants), or at the landscape scale, by the age classes of the stands comprising the forest.

The last subgroup, functional diversity, represents variation in ecological processes or interactions, such as nutrient recycling or nitrogen fixation. Most importantly, changes in compositional and structural diversity result in changes in functional diversity.

Spatial scale also affects our perceptions of diversity. For example, a strategy to maximize species diversity at the forest stand level does not necessarily add to regional diversity, as will be seen. Obviously, there is more to biological diversity than merely counting species. When discussing biological diversity, the subgroup (compositional, structural, functional), the level within the subgroup, and the spatial scale (local, regional, global) all need to be identified.

THE IMPORTANCE OF SCALE

The scale at which an object or a phenomenon is observed greatly affects the conclusions drawn from the observations. This is certainly true about scientific inquiry. Although scientists rarely deal explicitly with the effects of scale in their scientific studies, the conclusions they draw from their research are scale dependent. That is to say, explanatory principles change depending on the temporal and spatial domain considered in a study. Principles that apply at smaller scales of time and space do not necessarily apply to longer time periods and larger spatial scales.

The common perception of foresters that "there is more species diversity now than ever" serves to illustrate the importance of scale. A strategy of creating diverse habitats by maximizing the age-class structure (structural diversity) of forest stands across the landscape does indeed tend to increase species diversity (compositional diversity) at local scales. However, management that maximizes species richness locally often favors "generalist" organisms at the expense of "habitat specialists."

Colonizing species tend toward opportunism in their life habits. They are more likely to prosper under a variety of conditions and are often widespread in their distributions. Adding generalists at the local level is unlikely to add new species to regional diversity because the generalist species added locally are often abundant throughout the region. In contrast, loss of habitat specialists at the local level often results in their loss at the regional level as well, because habitat specialists are more localized in their distributions and are regionally less abundant compared to generalist species. And so, it does not automatically follow that maximizing species richness at the forest stand level will also increase regional diversity.

The point is that the various elements of diversity operate at a variety of spatial scales from local to global. Although there is no "right" spatial scale in which to consider biological diversity, a comprehensive approach to conserving and enhancing biological diversity includes considering how local management affects regional diversity.

FUNCTIONAL DIVERSITY - THE FORGOTTEN DIVERSITY

Functional diversity is the least tangible of the diversity subgroups (Fig. 1), and thus is often ignored when discussing biological diversity. Changes in compositional and structural diversity will, however, alter functional diversity - causing variations in ecological processes. Perhaps the best way to illustrate this is by using the example of old growth.

The rationale for maintaining old growth as a component in the landscape has centered around the critical habitat provided for associated species such as the red-cockaded woodpecker or the northern spotted owl. People identify readily with plant and animal species, and given the legal leverage provided by the Endangered Species Act once a species is listed by the Department of Interior's Fish and Wildlife Service, the rather narrow scope of the debate over old-growth forests is not surprising. There is, however, a more fundamental discussion concerning functional diversity and old growth that should be heard.

An old-growth forest is more than simply a collection of large, old trees. Instead, old growth should be viewed as an ecosystem that encompasses all phases of forest development from young trees growing in gaps created by windthrow or natural mortality to an uneven canopy dominated by mature trees. Old-growth forests have dead wood (both snags and downed dead wood) in a variety of diameters, heights (lengths), and states of decay. Depending on their size, large woody residues can persist on a site for decades or even hundreds of years. The diversity of structure, in both the living and

dead tree components, contributes to the multi-layered, complex nature of old-growth stands. The flora and fauna (compositional diversity) as well as how energy and nutrients are cycled (functional diversity) are closely related to structural features such as the dead standing and dead downed wood.

Perhaps the most important effect of these woody residues in old growth is on site quality. Woody residues have superior moisture holding properties compared to mineral soil (woody residues dry out more slowly), they are a major site of mycorrhizal root activity (especially during dry periods), and they can be important sites for nitrogen fixation both on and in the soil. Because of these functional properties, Jurgensen et al. (1977) recommend that woody material should be left after harvest to guard against a long-term reduction in site productivity. Others are making similar recommendations (e.g., Franklin et al. 1986). From an ecological perspective, dead trees are as functionally important as live trees.

Many foresters consider old growth to be decadent and wasteful and something that should be replaced by young, fast growing, thrifty forests. Common rotations for managed forests are only a fraction of the time necessary to develop old-growth forests. In addition, management practices often result in structural simplifications that include eliminating dead trees and downed logs, reducing the range of tree sizes and growth forms, and using uniform tree spacing (Franklin et al. 1986). While such practices may appear to be "good forestry" in the short term, they may actually reduce productivity over large areas and over long time periods (i.e., questions of scale).

When evaluating forest health from the point-of-view of a functioning ecosystem, old growth might well represent a healthy forest. Currently, there is a great deal of discussion about maintaining long-term site productivity. Old growth can teach us much about how to practice sustainable forestry!

FOREST FRAGMENTATION

A land-use pattern characteristic of a human-dominated landscape is one in which large, continuous tracts of natural habitat become increasingly fragmented and isolated by a network of developed lands

(Wilcove et al. 1986). Fragmentation results in increased amounts of edge environments within the landscape. Edges have always been of interest to wildlife biologists because they provide critical habitats for many game species such as deer and grouse. Increased edge environments do not constitute habitat improvement for all species.

In the fragmented woodlots in central and eastern United States, many songbirds common to the eastern deciduous forest have declined in numbers during recent decades, and most of these declining species share several

ecological traits. They are obligatory forest-dwellers and migrate long distances to winter in the American tropics, they are open nesters (as opposed to cavity nesters) with many species nesting near or on the ground (e.g., the ovenbird), they have steadily disappeared from smaller patches of forest habitat and now persist mainly in extensive unbroken tracts, and they have inadequate defenses against brood parasitism (Robbins 1979). Common among the bird species in decline are warblers, vireos, flycatchers, tanagers, and thrushes. To maintain viable populations, these species require interior forest conditions found in large forested tracts and away from forest edges.

The effects of forest fragmentation on species other than birds is less certain. In general, large mammals with low populations densities and extensive home ranges suffer more from habitat fragmentation than do smaller species with more localized habitat needs and larger populations. Vermeij (1986) speculates that ectothermic (cold-blooded) animals, with their low metabolic rates and long periods of inactivity, may be less susceptible to habitat fragmentation and environmental stress than endothermic (warm-blooded) animals, whose high metabolic rates and continuous activity make for less tolerance to even temporary adversity.

In terms of plants, insect-pollinated flowering plants may be more prone to extirpation than wind-pollinated plants (Vermeij 1986). The rationale for this conjecture is that pollination by insects permits plants to persist at lower densities and therefore make them more susceptible to local extinction. To my knowledge, there is no evidence that tree species have been lost from the temperate forest due to forest fragmentation. Landscape patterns created by fragmentation, however, do affect the structure and composition of the remaining forest patches. For example, several studies of forest woodlots in the midwestern United States indicate that position within the woodlot is more important than stand age in determining tree composition (Ranney et al. 1981, Whitney and Runkle 1981).

While the impacts of forest fragmentation on specific plant and animal species are not fully understood, it is clear that fragmentation affects species in two general ways. First, there is a direct effect represented by the loss of habitat, and second, there is an indirect effect resulting from the isolation of populations remaining in the residual patches. Small, isolated populations are

much more prone to extirpation than large populations that are geographically widespread.

Cutting patterns often add to forest fragmentation. For example, the strategy of dispersing small clearcut patches throughout the landscape on Federal timberlands in the Douglas-fir region (i.e., the staggered-setting clearcut pattern) may not make sense either economically or ecologically (Franklin and Forman 1987). Using this strategy, large tracts of intact forest are eliminated by cutting only a small percentage of the forest. The approach maximizes the high-contrast edge between primeval forest and cutover areas and disturbance regimes (especially fire and wind) may be significantly altered. Operational efficiency is reduced by scattering small clearcuts across large areas and an extensive road network must be developed and maintained in order to provide access. As an alternative, Franklin and Forman (1987) suggest approaches that feature progressive or cluster cuts that reduce the amount of edge created by cutting, and reduce the contrast between cut and uncut stands.

A NEW SILVICULTURE?

Is a new silviculture needed to incorporate nontimber values such as concerns about biological diversity into forest management? In my judgement, the answer is no. Silviculture has been defined as the art and science of producing and tending forests (Smith 1962). This classic definition and the basic silvicultural systems as outlined by Dave Marquis in this volume are broad enough to provide means of integrating biological diversity and forest management. Moreover, foresters are already involved in developing and applying silvicultural treatments that protect and enhance nontimber values. This trend is well established and irreversible – “the days have ended when the forest may be viewed only as trees and the trees only as timber.”

Tending forests will continue to be the challenge facing silviculturists in the 1990's. Given this challenge, the view that biological diversity is somehow ancillary to the major goals of forestry is myopic and self-defeating. Integrating actions to protect biological diversity, with all its related elements, into forest management will enhance both commodity as well as noncommodity values alike. The solution is not creating a new silviculture – the solution is creating a new perspective.

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Biological Diversity

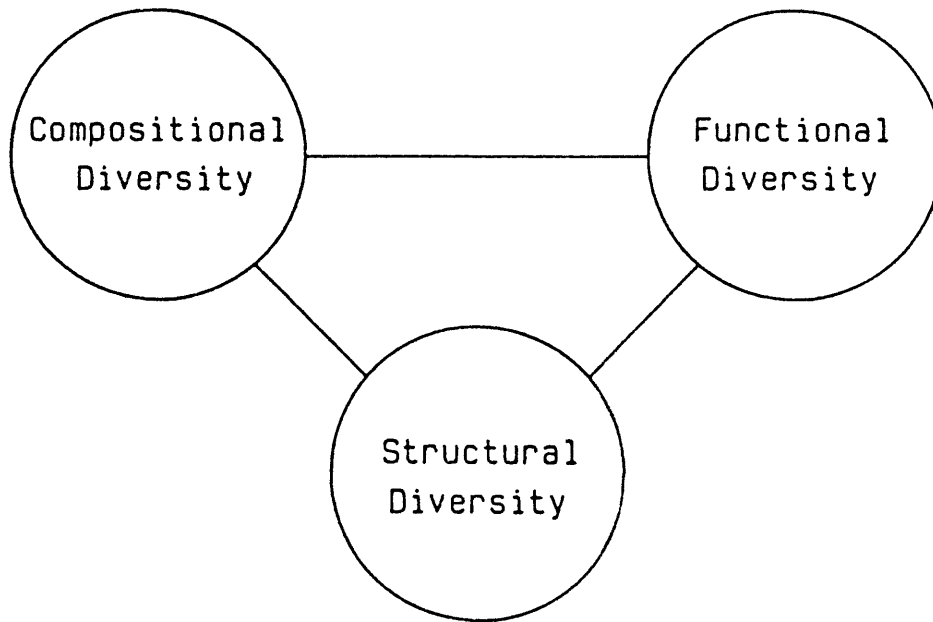


Figure 1. The interrelated subgroups of biological diversity.

Compositional Diversity

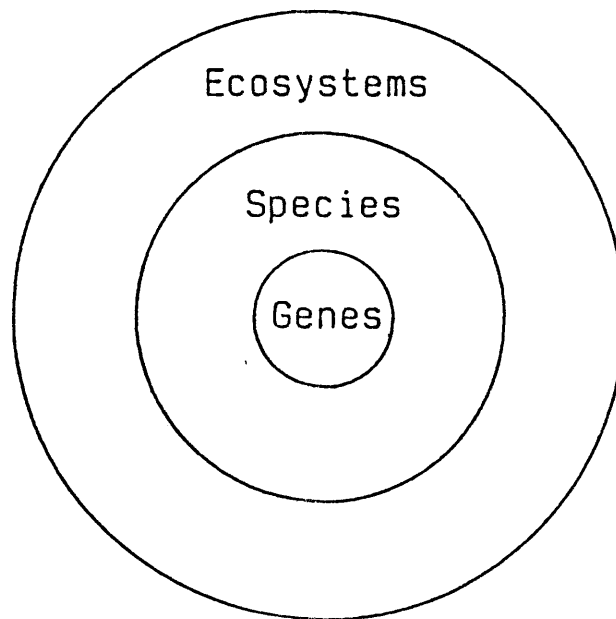


Figure 2. Each subgroup can be further divided into hierarchical levels. In the case of compositional diversity, commonly recognized levels include genes, species, and ecosystems.

THE FOREST SERVICE OPENS A LABORATORY FOR THE GENETIC ANALYSES OF TREES¹

Richard G. Miller, M. Thompson Conkle and Sharon T. Friedman²

Abstract

In February 1988, the Forest Service established an electrophoresis laboratory at Placerville, California to serve the National Forests. The new laboratory will process seeds and tree samples to provide forest personnel with genetic information about relative amounts and geographic patterns of natural variation. Tests at the laboratory will give forest managers the means for evaluating the genetic consequences of stand management practices, and tree improvement workers will have access to new quality control measures for many aspects of their on-going programs.

Additional keywords: Tree improvement, genetic diversity, isozyme.

INTRODUCTION

The genetic quality of seedlings is a major concern in Forest Service planting operations. Accordingly, Forest Service Regions and National Forests have developed and implemented comprehensive tree improvement programs during the last 25 years. Steps have been taken to account for natural adaptation by mapping seed zones, certifying seed collections, and applying seed transfer

rules. Emphasis has been given to collecting seed from large numbers of trees (including plus tree selections) within a specific seed zone to maintain high levels of adapted genetic variation. Plus tree selections have been made for some species/seed zones solely to provide a seed source to ensure that adequate genetic variation is maintained in seedlots used in the reforestation program. Most Forest Service plantations are now established with full knowledge of seed origin.

Intensive tree improvement programs have been initiated for several species where the investments can be justified. These programs include: defining breeding zones, selecting plus trees, planting progeny tests to evaluate the genetic worth of the selections, and establishing seed orchards for seed production. The base populations for each breeding zone include large numbers of plus trees to provide high levels of genetic diversity for continuous improvement in future generations. As of October 1, 1988, National

Forest personnel have selected 101,406 plus trees, planted 1,319 progeny tests that cover 8,508 acres, and established 204 seed orchards on 2,861 acres (table 1). Advanced generation selection and breeding programs for high priority species are under way in some Regions.

Table 1.—National Forest System tree improvement program statistics as of October 1, 1988.

Region	Headquarters	Selections		Seed Orchards/ Clone Banks		Progeny Tests	
		Species	Number	Number	Acres	Number	Acres
1	Missoula	6	8,192	13	141	52	534
2	Denver	3	452	--	--	4	6
3	Albuquerque	2	437	--	--	--	--
4	Ogden	2	874	--	--	8	141
5	San Francisco	8	7,663	12	192	49	266
6	Portland	26	75,629	117	903	767	6,219
8	Atlanta	14	3,422	27	1,302	301	987
9	Milwaukee	35	4,737	35	323	138	355
10	Juneau	--	--	--	--	--	--
TOTALS			101,406	204	2,861	1,319	8,508

¹ Presented at the Northeastern Forest Tree Improvement Conference, July 7, 1988, at Pennsylvania State University.

² Forester/Geneticist, National Forest System, Washington, D.C., Plant Geneticist, Pacific Southwest Forest and Range Experiment Station, USDA Forest Service, Berkeley, California, and Laboratory Director, Eldorado National Forest, Placerville, California.

Rare and endangered species are protected in their native environments, and there is growing awareness of the need to identify the unique genetic characteristics of these species. There is also growing concern and need for information about the genetic effects of various silvicultural systems on the common and wide spread species. Both needs for information are driven by the realization that certain genes and gene complexes are vulnerable to permanent loss. Protecting rare species and choosing silvicultural systems to maintain high levels of adapted genetic variation are priority goals in forest genetics programs.

Forest Service policies also mandate applying management strategies to maintain natural diversity; however, Forest personnel have had very limited means to identify and monitor a primary component of natural diversity—genetic variation. Fortunately, there is a timely and efficient way to obtain information about genetic variation. Researchers have developed procedures to identify the products of numerous genes, and those procedures can now be used to evaluate diversity and map geographic patterns of variation. These gene products are also excellent markers for identifying particular trees, their seed and their pollen.

In February 1988, a decision was made to establish an electrophoresis laboratory to produce state-of-the-art genetic information. Two basic objectives will be addressed: to provide analyses in support of wide-ranging and complicated tree improvement programs, and to develop base-line genetic data useful for gene conservation and long-range population management.

The laboratory will perform analyses that identify different forms of enzymes, called isozymes. The enzyme variants provide precise genetic data for a large number of genes within each sample of living tissue. The gene frequencies obtained from those tests provide a timely way to inventory the amount and geographic distribution of genetic variation in native forests. The same gene markers are highly valuable tools for quality control in numerous phases of on-going tree improvement programs.

LOCATION AND ORGANIZATION OF THE LABORATORY

The National Forest Genetics Electrophoresis Laboratory (NFGEL) is located at the Placerville Nursery on the Eldorado National Forest, 45 miles east of Sacramento, California; it is within a mile of the Institute of Forest Genetics (IFG). The new laboratory has offices for the staff, space for working with incoming plant materials, and a large area for conducting laboratory analyses.

National Forest field personnel will be responsible for proposing projects. The laboratory staff will work with the Regions and National Forests to define their special information needs. Interpretive final reports will be delivered to field personnel, and the laboratory staff will be available for consultation. Meetings involving user groups, laboratory staff, and research personnel will be arranged when needed. A steering committee will establish basic policies and resolve conflicts in priorities.

TYPES OF ANALYSES

Forest Service research to adapt electrophoresis techniques to forest trees was initiated in 1962 at the Institute of Forest Genetics (IFG), Pacific Southwest Forest and Range Experiment Station (PSW). Techniques, equipment, and knowledge have improved steadily since then, and electrophoresis has evolved into a powerful tool for analyzing forest species.

This form of electrophoresis refers to a system where enzymes with slightly different molecular structures separate into distinct bands in starch gels when the gels are charged with direct current. Different gene products, the sometimes numerous alleles of specific genes, are "read" as colorfully stained enzyme mobility variants on the gels. For the enzymes analyzed, the rule is one enzyme equals one gene. The procedure has been used to identify genotypes for over 50 genes per tissue sample.

Eight types of analyses have been identified as examples of work the laboratory will perform:

1. *Map patterns of genetic variation.* Isozyme analysis of seeds from trees scattered over wide areas can provide valuable information about geographic patterns of genetic variation. While some species have very little geographic variation, and therefore have broad seed zones, other species change genetically over relatively short distances and therefore require much smaller zones to ensure adaptability. Isozyme data can also be used to refine seed zone and breeding zone boundaries, and to assist with the allocation of plus trees to seed orchards.

2. *Evaluate management effects on genetic diversity.* Questions are frequently asked about the effects of various silvicultural systems on genetic diversity. Specific analyses will be made to determine if the regeneration is more variable, less variable, or about the same as that of the preceding generation. This type of analysis usually begins with a genetic description of the original stands, followed by describing variation in the seedlings and young trees present in the new stands.

3. *a) Check compliance of cone collectors.* The Forest Service generally collects over 50,000 pounds

of seed annually. Over half of this seed is collected by contractors and/or Forest Service employees from designated stands within seed zones. By analyzing seeds from single cones collected from several trees growing within the designated stands, the laboratory staff can estimate the gene frequencies of these trees and compare this to the gene frequencies present in the final bulked seed collection. Likewise, if single-tree collections were requested, tests could verify that pure collections were obtained from the appropriate trees.

b) Check commercial seedlots. In the past 10 year period, the Forest Service purchased an average of 4,100 pounds of seed annually from commercial sources. The origin of these commercial seedlots could be verified by collecting new seed samples from the appropriate stands and then testing for close genetic relationships between the commercial and test seedlots.

4. Identify ramets, families, provenances, and seedlots. Mistakes in labeling occur in seed banks, nursery beds, field tests, and seed orchards despite the best precautions and controls geneticists and nursery managers implement to prevent them. Isozyme analysis of suspicious materials will often help reveal identities and raise the consciousness of workers to avoid similar mistakes in the future.

5. Verify specific crosses. Isozymes are the only readily available means for checking the identity of controlled crosses. As we move into advanced generation breeding programs, quality control for pollination and verification of parentage is essential.

6. a) Estimate pollen dispersal and seed orchard contamination. Pollen distribution and orchard contamination can be estimated using genetic markers from pollen sources within seed orchards and from pollen sources within surrounding stands. This knowledge will help managers to adjust procedures to achieve their seed orchard objectives.

b) Check effectiveness of supplemental mass pollination techniques. In order to make reasonable estimates of genetic gain from mass pollinated orchards, we need to know that the desired pollen fertilizes the orchard. Isozyme markers will also be used to develop cost-effective supplemental mass pollination techniques.

7. Quantify the rates of inbreeding and outcrossing. Knowledge of the breeding system is critical to the management of stands and seed orchards. In some cases it may not be wise to depend on natural regeneration because of a stand's narrow genetic base and tendency for substantial inbreeding. Knowing the proportions of selfed and outcrossed seeds produced by clones in seed

orchards will provide the basis for modifying seed orchard management strategies.

8. Monitor genetic diversity in recurrent mass selection programs. The genetic make-up of plantations changes in response to natural selection and in response to the chance elimination of trees with specific genetic traits. Monitoring genetic change within a stand over a rotation will lead to understanding relationships between genetic factors and stand development. Monitoring variation over several rotations will lead to understanding evolutionary processes in forest populations. Isozymes can also be used to select individual trees from a population of selected trees to ensure that genetic diversity is maximized in the resulting plantations.

BENEFITS

The Forest Service will achieve benefits in two broad areas: 1) increased precision and application of new quality controls in Regional tree improvement programs, and 2) production of extensive new base-line information on genetic diversity for a variety of forest tree species that can be used to validate management strategies.

Including the best selections in breeding programs will increase the potential wood production on National Forest System lands. Conversely, if selection is compromised, the potential will not be achieved. Errors in seed and/or seedling labeling and handling, from seed collection through seedling outplanting in seed orchards or progeny tests, are inevitable. Using isozyme analyses to validate specific crosses/selections/progenies will help geneticists confirm that they are indeed selecting the specific genetic material that is desired. This is especially significant in forest genetics programs because of the extended time periods involved in evaluating performance of progenies derived from breeding programs. Eliminating parents from advanced generation programs is very costly as the progenies involving these parents must be rogued, and, more important, the genetic base in the program may be reduced. This may require adding new material to the breeding population, and this most likely will reduce the genetic gain in the short term. It is critical to base selections on all available information to reduce the probability of having to make changes in later generations. Isozyme data is another tool that will help geneticists develop confidence in their selections, and thereby achieve potential wood production goals sooner.

Gene pool conservation and genetic diversity have been topics of debate over the past few years. Basically, what effect does our timber management program have on the gene pool? On genetic diversity? Very little substantial information is available to answer these questions. The

Forest Service, managing a wide-range of diverse habitats, has an opportunity to provide international leadership on the effects of management on genetic diversity and the gene pool, as both managed and relatively pristine populations of forest trees are available for study. Monitoring allele frequencies over time on sites receiving different silvicultural treatments will provide the necessary data. With this data in hand we can support our management strategies in respect to effects on the gene pool, and, if necessary, we can modify our treatments if data shows there are in fact adverse impacts on genetic diversity.

SUMMARY

The establishment of an electrophoresis laboratory will benefit the Regions' tree improvement programs, seed procurement programs, and the overall timber management program. The lab is located in existing facilities at the Placerville Nursery, and will be operated by a professional staff. The Forest Service is implementing state-of-the-art technology developed by Forest Service Research at PSW, and will continue to take advantage of the latest information as it is provided by the scientists at the Station.

Data will be used to validate specific genetic materials adding confidence to our advanced generation tree improvement programs, and to provide information on the effects of timber management on genetic diversity and the gene pool.

Developing Stand Density
Guides for Optimum Growth of
Timber Species on the Salmon
National Forest, Idaho

Douglas D. Basford
Silviculturist
Salmon National Forest¹

John P. Sloan, Russell A. Ryker (retired)
Forestry Sciences Lab
Boise, Idaho

ABSTRACT

Presents a method for estimating the growing space required by trees of given diameters to maintain a specific rate of diameter growth at breast height. Growth data were derived by increment-coring Douglas fir (*Pseudotsuga menziesii*), ponderosa pine (*Pinus ponderosa*), and lodgepole pine (*Pinus contorta*), stands throughout their range on the Salmon National Forest in central Idaho. The model accurately predicted 20-year diameter growth on ponderosa pine growth plots in three locations in the western United States.

Stand density is an important consideration in timber management. Although easily manipulated, stand density affects all the products and uses of a forest. Until recently, foresters on the Salmon National Forest in east-central Idaho have not had reliable stocking guides for their dominant timber-producing species. Past thinning efforts usually have not created enough growing space, or the thinning was delayed so long that the trees had small crowns and could not respond to the thinning treatment as predicted by the stocking guides. Relative Stand Density Index (Drew and Flewelling 1979) and Reineke's Stand Density Index (Reineke 1933, Gingrich 1967) provide useful formats but do not show how to choose density levels to meet specific management objectives.

Ideally, the relationship between stand density and growth is established through repeated measurements over time in permanent sample plots at a variety of sites and at several density levels. Unfortunately it takes many years before such research produces results. Meanwhile, timber specialists must continually decide stand densities, relying on experience and extrapolations from published

data that may be of questionable relevance to the timber stands at hand. Large errors in stocking density cannot be easily corrected; moreover, such errors can result in costly losses in timber production. For these reasons the Intermountain Region of the Forest Service, U.S. Department of Agriculture supported an administrative study in the Salmon National Forest, to develop stocking guides that could quickly be implemented for ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.), lodgepole pine (*Pinus contorta* var. *latifolia* Engelm.), and Douglas-fir (*Pseudotsuga menziesii* var. *glauca* [Beissn.] Franco). Assuming that other forest managers face the same predicament, in this article the authors describe the development and application of their stocking guides.

METHODS

Our approach to developing stocking guides was based on evidence that to achieve reasonable growth from many forest sites in the Intermountain Region we must maintain a more uniform spacing between crop trees than we have in the past. Basal area and/or trees per acre measures by themselves, average different diameter sizes and densities over the total area included within the stand boundaries. The result is densities remain higher than desired in parts of the stand even after thinning. This is not a serious problem on the best sites because trees are capable of growing at a reasonable though reduced rate. But on the poor-to-average sites this usually results in little or almost no stand response after thinning. This conclusion is supported by data collected from thinned stands on the Salmon, Targhee, and Dixie National Forests. In dbh classes between 5

¹ Presented at the National Silviculture Workshop, Petersburg, Alaska, July 10-13, 1989.

and 14 inches, there has been little growth response to thinning because spacings were usually too narrow.

The growth equations developed on the Salmon National Forest were derived from the analysis of increment cores rather than from the traditional measurement of permanent sample plots. Trees of various sizes, spacings, and habitat types were sought for measurements of diameter growth rates, distance to adjacent trees, and crown ratio. In this way, a great deal of data could be obtained in a short time.

Sample trees were selected from the center of groups with relatively even spacing between trees and uniform diameters. Also, all groups had to be free from mortality and from insect and disease attacks. In other words, it was important that sample trees had experienced consistent competition on all four sides since the stand first came into competition with surrounding trees and that the growth rates had not been reduced by other external biotic factors. Thus one could reasonably assume that reductions in growth rates were related to spacing.

Examination of increment cores showed a consistent pattern of radial growth. Typically, there were as few as one or as many as several periods of relatively uniform growth. Subsequent growth rates were slower and each growth period was separated from the next by a recognizable narrow transition (Fig. 1). After a small amount of experience, field crews became proficient in identifying the breaks between the growth periods.

Because maximum growth rates vary by tree size, species, and site quality, sample cores were also taken from large trees that showed no sign of intertree competition, past or present. Analysis of these "free-to-grow" trees showed periods of uniform diameter growth and reduction points similar to the trees in competition. But the growth reductions appeared to be related only to tree size and in this case could not have been caused by intertree competition. These growth rates were considered to be the productivity potential for that site. Sample trees under competition were required to have a first period growth rate similar to that of the free-to-grow trees in that habitat type (Table 1) because there should not have been intertree competition at that age. If a tree's growth rate was much below the potential on that site for the first growth period, we assumed it was due to an unidentified cause such as nearby trees that have since disappeared, and that tree was not included in the sample.

In addition to site and plot characteristics, the following measurements were made on each sample tree: species, diameter at breast height (dbh), height, live crown ratio, age, and rings-per-inch for each growth period.

Increment cores from both uphill and downhill sides were taken from each sample tree to verify growth periods, and measurements were averaged.

From this, the following information was obtained: (1) reductions in diameter growth rates of free-to-grow trees by species and habitat type, (2) tree space requirements related to dbh and diameter growth rates, and (3) crown ratios in relation to dbh and spacing.

Ponderosa pine, lodgepole pine, and Douglas-fir were all included in the study. Using sample tree data for the three species, growth rates for each were plotted against growing space and dbh. Regression lines were drawn to represent the minimum space required to achieve the average growth rate for that period (Fig. 2). Regression equations and coefficients of determination were then calculated. Equations were also constructed for spacing and dbh for several different crown ratio groups.

For all regressions, plots of residuals versus predicted values were examined, and standard deviations about the regressions were calculated as measures of reliability.

The data from free-to-grow trees were used to determine the potential diameter growth rates until intertree competition begins and to determine the average diameter at growth rate culmination for each different species and habitat type.

Finally, for ponderosa pine and Douglas-fir, crown ratios between 20% and 90% were plotted against growth rates of trees free from competition and from silvicultural treatment. Because the ponderosa pine and Douglas-fir curves were so similar, the data were combined to make one curve.

Our growth rate equations represent an attempt to more closely model the way in which tree growth has been observed in the field. In other words, our method is based on individual tree growth rather than on net growth of the whole stand.

RESULTS AND DISCUSSION

The criteria for sample trees made it difficult to find a large number of trees in some diameter ranges. Large trees and trees smaller than 3 inches dbh were especially rare. Generally, sample trees were easier to find on drier sites where initial spacings are usually wider than on moist sites.

From the free-to-grow trees, the dbh at each culmination point and growth rates for the different growth periods

were tabulated by species and habitat type (Table 1). On all Salmon National Forest sites growth rate for ponderosa pine first changes at approximately 13.2 in. dbh. Growth slows from about 7.5 to 12.4 rings per inch. The second growth-reduction point is at 19.8 in. when the growth rate slows to 19.8 rings per inch.

For Douglas-fir, the dbh at the first growth rate reduction varies by site, but the greatest average growth rates are about 8 to 9 rings per in. (Table 1). The lodgepole pine growth rate drops from 7.1 to 11.8 rings per inch at 9.5 in. dbh. The number of trees sampled in each habitat type are too few to express confidence in the mean. Site indexes in Table 1 are higher than the Salmon National Forest timber inventory shows for similar sites because most of the inventory site trees have had competition. Inventory site trees are more realistic to use for most height projections.

Table 2 shows tree spacing and dbh regression equations for ponderosa pine, Douglas-fir, and lodgepole pine. The equations represent the maximum average growth rates. In each, the independent variable, X , is the dbh and the dependent variable, Y , is the spacing. These equations are plotted in Figures 3-5. Confidence intervals for all of the regressions are depicted in Figure 6.

The ponderosa pine graph (Fig. 3) is similar to the Douglas-fir graph (Fig. 4). For both, the diameter growth rate before the first regression line depends on the crown ratio. Figure 7 can also be used to determine ponderosa pine and Douglas-fir growth rates in the first period based on crown ratios. The diameter growth rate for the second regression lines is 16 rings per in. for both species. The third growth rate is 32 rings per in. for ponderosa pine and 30 for Douglas-fir. After the third regression line, diameter growth falls to 55 rings for ponderosa pine and 64 rings for Douglas-fir. For lodgepole pine, the growth rates are 9, 19, 35, and 63 rings per in. (Fig. 5).

Another finding was that average crown ratios were very consistent for any given dbh and tree spacing. Table 3 verifies this observation by showing spacing vs. dbh regression equations for several crown ratio groups by species. The R^2 values range from 0.52 up to 0.90. The data came from trees under competition.

Finally, in order to predict how a stand will respond to thinning, the relationship between growth rate and crown ratio was plotted for ponderosa pine and Douglas-fir free from competition. Because the curves for the two species were so similar, the data were combined to form one curve (Fig. 7). The R^2 of this regression is 0.59. Data were not available to construct a relationship of crown ratio to growth rate for lodgepole

pine, but this curve would probably be similar to the one in Figure 7.

On the Salmon National Forest, Douglas-fir occurs over a greater range of elevation and site quality than ponderosa pine and lodgepole pine. Because growth reduction occurs at a lower dbh on poorer sites in free-to-grow trees, there is more variability for Douglas-fir than for the other species (Table 1). Growth rates before the first reduction point do not vary widely between species or sites. On three habitat types for ponderosa pine, five for Douglas-fir, and one for lodgepole pine, average growth rates for the first growth period range from 7 to 9 rings per inch.

The regression equations in Table 2 represent the minimum space required to achieve the maximum average growth rate for a given average dbh. Equations have been developed for three growth periods per species. The predictive abilities of these equations are consistently high, with only two R^2 values below 0.89. The data on which these equations are based came from trees ranging in size from 1 to 21 in. dbh. As can be seen in the confidence interval widths (Fig. 6), most of the sample trees were in the 4- to 12- in. dbh range. The user must be careful not to extrapolate beyond the range of the independent variable because these are empirically derived equations. Extrapolation beyond the range of the data may lead to gross errors in estimation.

Each of the nine regression equations in Table 2 are graphed according to species in Figures 3, 4, and 5. The lines depict the diameter where trees at any given spacing will reduce their growth rate to that of the next lower level. The solid lines indicate the range of the data. Growth rates are indicated above each line for that growth period. The growth rate for the first growth period of ponderosa pine and Douglas-fir (Figs. 3 and 4) has been refined more than for the lodgepole pine. Here, the growth rate in the first growth period is related to crown ratio because a tree's ability to attain the maximum diameter growth rate depends on the size of its crown and its ability to carry on photosynthesis.

The relationship between crown ratio and growth rate of ponderosa pine and Douglas-fir is shown in Figure 7. At first a regression was done for both species, but the curves were so similar that the data were combined to form one curve. The purpose of this curve is to predict the growth rate of trees after thinning because the potential of a tree with a small crown is not the same as one with a full crown. Experience on the Salmon National Forest has shown that when crown ratios are below 30% there is little response to thinning.

The primary use of this model is to predict the future diameter growth of both thinned and unthinned stands for improved forest management. This should result in achievement of spacings that will produce desired tree characteristics and desired growth.

Table 4 shows the minimum growing space needed by 10-in. trees to maintain three different rates of growth. This is compared with the equivalent stand density indices for each. The maximum growth rate ceases at 10-in. dbh and growth slows before crown closure. Maximum timber production occurs at the intermediate growth rate. Higher densities should produce significant mortality.

The regressions in Figures 3, 4, and 5 show that the growth rates of ponderosa pine and Douglas-fir are similar, but are different from the growth of lodgepole pine. The regressions also indicate that Douglas-fir and lodgepole pine need as much or more growing space as ponderosa pine to attain the maximum diameter growth rate. In fact, Douglas-fir and ponderosa pine are able to sustain about 25% of their maximum growth rate at narrower spacing than lodgepole pine.

It will take several years to collect enough data on the Salmon National Forest to test this model. Useful data from permanent growth plots are rare within this geographic area. But we were able to test the growth model against actual growth on ponderosa pine plots from three different locations in the western United States. Table 5 compares predicted growth and actual growth from 6 plots in Arizona, 12 plots in South Dakota, and 5 plots in central Oregon. The Arizona and South Dakota studies covered two 10-year periods, with a thinning at the beginning of each period. During the first 10 years, the error of predicted versus actual growth ranged from +14% to -11.4%. During the second 10 years the error dropped to a range of +3.8% to -6.8%. This reduction in error in the second decade has also been observed in field data collected on the Salmon National Forest. Thus, to predict the growth of a stand, it is important to use the average growth of an unthinned stand or the response of a thinned stand after it has had ample time (probably 10 years) for the growth rate to stabilize. The 25-year study from central Oregon had only one initial thinning with no midterm treatments. Overall, the model tended to slightly underestimate diameter growth, but the R^2 value of actual vs predicted growth was calculated to be 0.94. The average starting

diameters of the plots ranged from 2 up to 10 in., and average spacings were 6.6 ft to 32.5 ft. There was no significant correlation between degree of error and spacing or size of tree.

MANAGEMENT APPLICATION

Our growing-space model is an improvement over the conventional stand density index because it emphasizes growing space between trees rather than average size/density indices. Thus, it allows thinning of stands to a given spacing, which is a more accurate way to reach management targets, because it considers only the land on which trees are actually growing and not the total area, including gaps in the stand. It also takes the crown ratio into consideration and whether the trees can fully respond to release (Table 3 and Fig. 7).

Our spacing regressions will help foresters select a spacing that maintains maximum individual tree growth attainable in a specific stand. If we choose closer spacing, we will get slower individual tree growth, but greater total stand growth.

Proper use of the spacing regressions requires that silvicultural treatments be prescribed through the remainder of the rotation to the final harvest. If spacing is to be kept relatively uniform, the size of the trees at harvest dictates the number and spacing of trees left after each thinning. Lack of consideration for final tree size and the number of intermediate cuts could result in irregular spacing and lost diameter growth, or too wide a spacing and failure to fully utilize the site.

It is beyond the scope of this paper to present the computer model that was developed from these equations but all the information needed to use the model has been included. Our next step will be to further improve the model.

With this model it is possible to maintain a consistent rate of diameter growth in even-aged stands. But as others have reminded us (Leak 1981, Ernst and Knapp 1985), we must continue to evaluate recommended stocking levels to see how close they come to satisfying our management objectives. Through this process, refinements can be made and the stocking guides can be improved.

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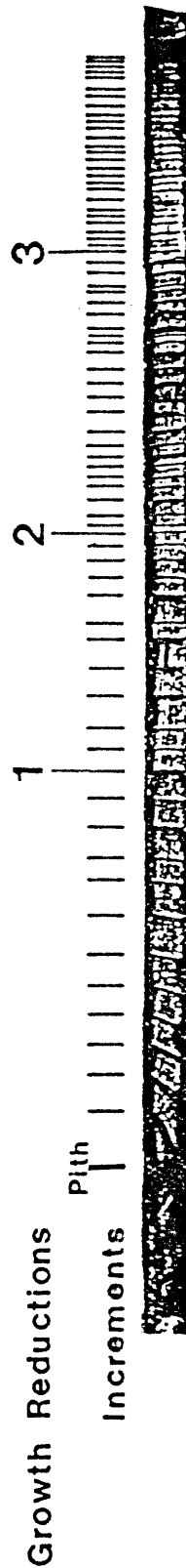
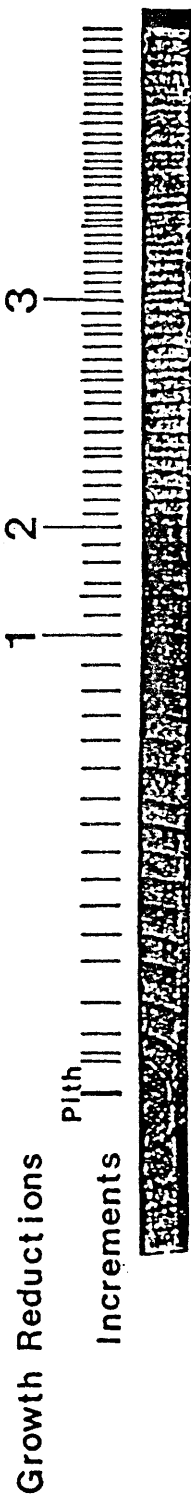


Figure 1--The growth, growth periods and growth reductions delineated on sample cores. Rings per inch (RPI) are computed for each growth period. The growth periods are more readily seen after viewing a number of cores. It may take several tries before the mind and eye are coordinated.

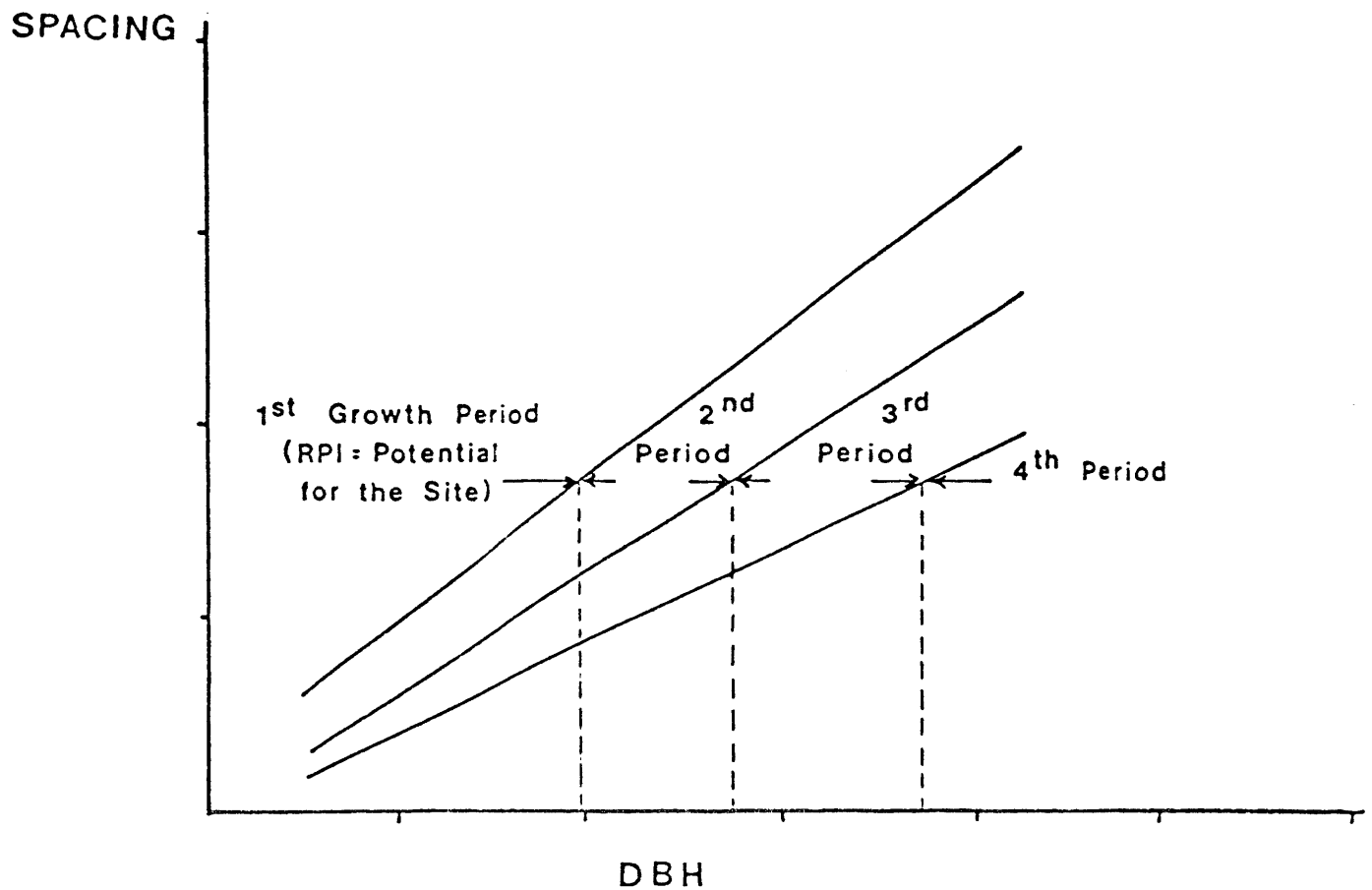


Figure 2. Spacing or competition curves. Each curve represents the minimum space for trees of specified dbh. Closer spacing of trees of that size results in reduced diameter growth rates.

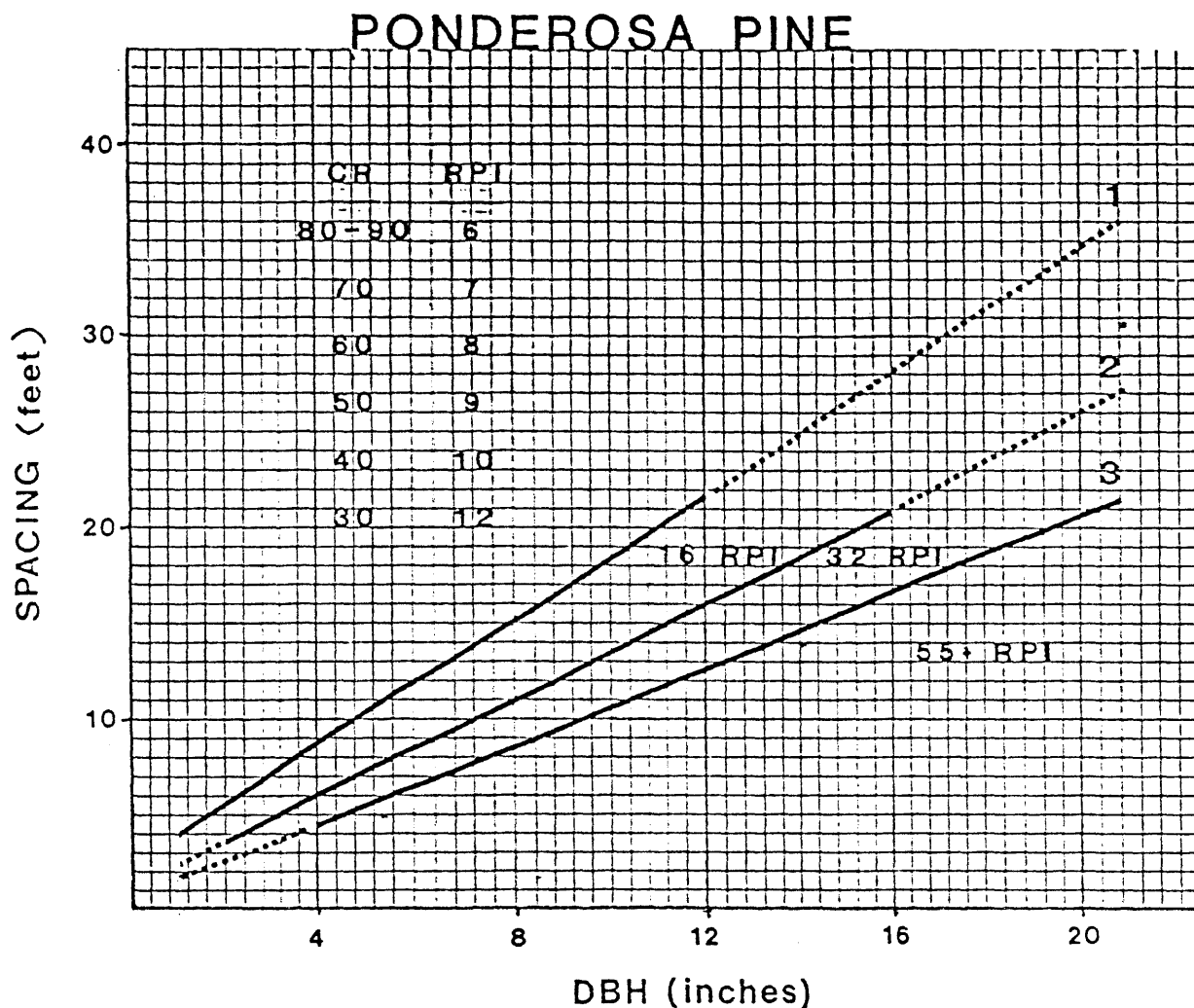


Figure 3--Diameter growth rates (rings per inch) associated with spacing and tree size, ponderosa pine, Salmon National Forest. Confidence intervals for each regression are depicted in figure 6. Equations for each regression are presented in table 2.

Regression 1 represents the minimum space required for ponderosa pine to achieve the maximum average diameter growth rate for a given crown ratio. Regression 2 represents the space to achieve 16 RPI, and regression 3 represents the minimum space for 32 RPI.

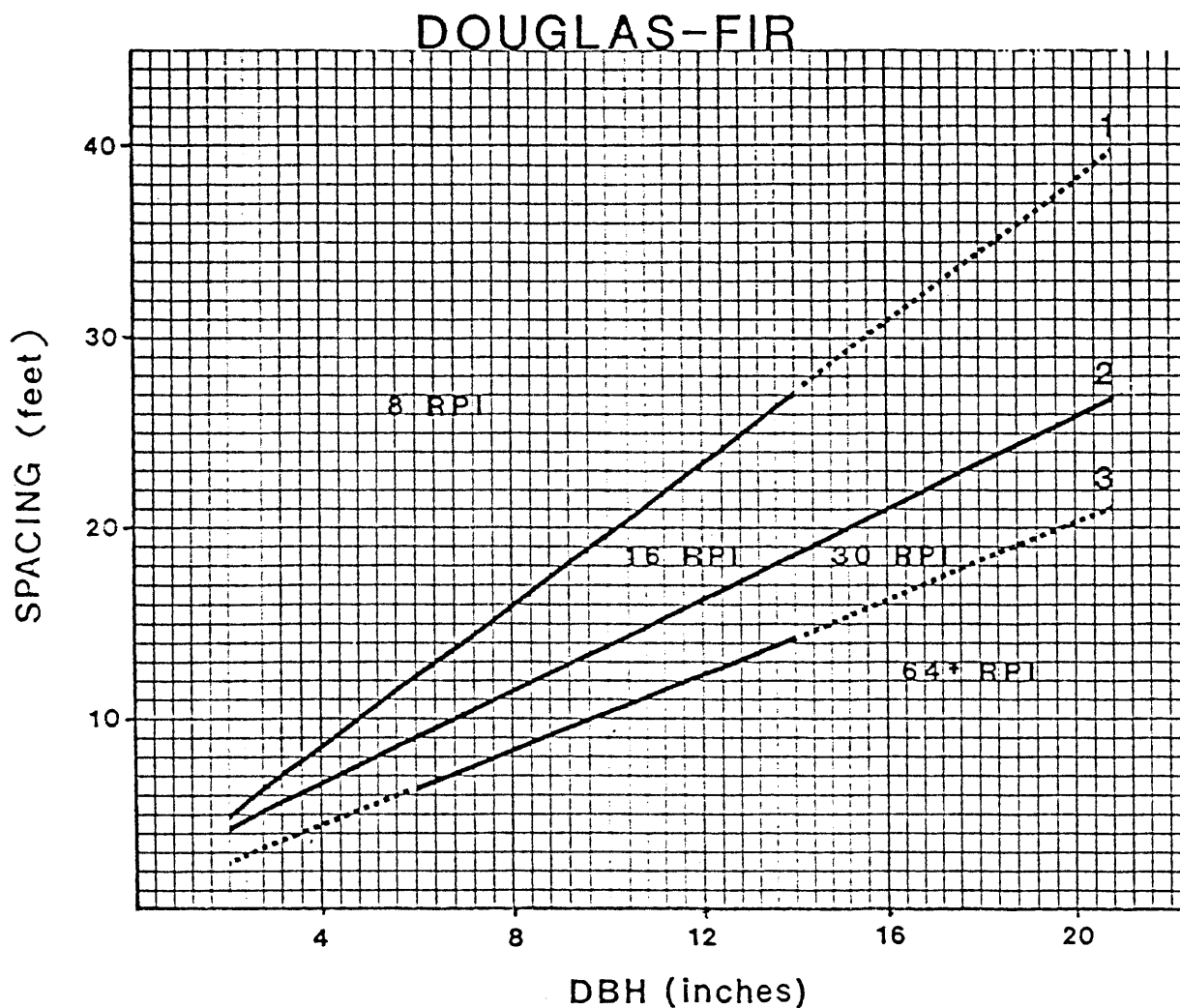


Figure 4—Diameter growth rates (rings per inch) associated with spacing and tree size, Douglas-fir, Salmon National Forest. Confidence intervals for each regression are depicted in figure 6. Equations for each regression are presented in table 2.

Regression 1 represents the minimum space required for ponderosa pine to achieve the maximum average diameter growth rate of for a given crown ratio. Regression 2 represents the space to achieve 16 RPI, and regression 3 represents the minimum space for 30 RPI.

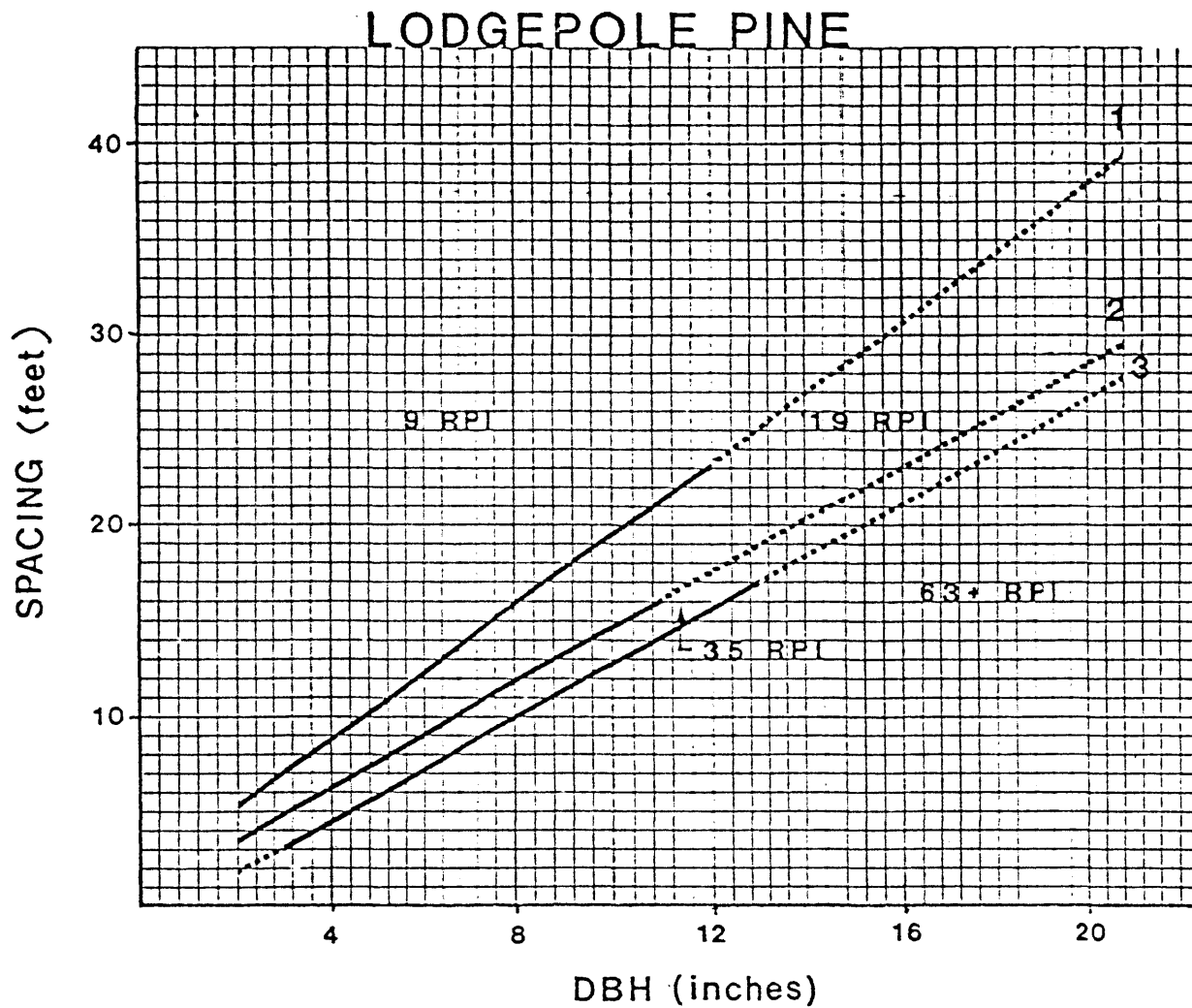


Figure 5--Lodgepole pine diameter growth rates associated with tree spacing and size. Confidence intervals for each regression are depicted in figure 6. Equations for each regression are presented in table 2.

Regression 1 represents the minimum space required for lodgepole pine to achieve the maximum average diameter growth rate of 9 RPI. Regression 2 represents the minimum space to achieve 19 RPI and regression 3 represents the minimum space for 35 RPI.

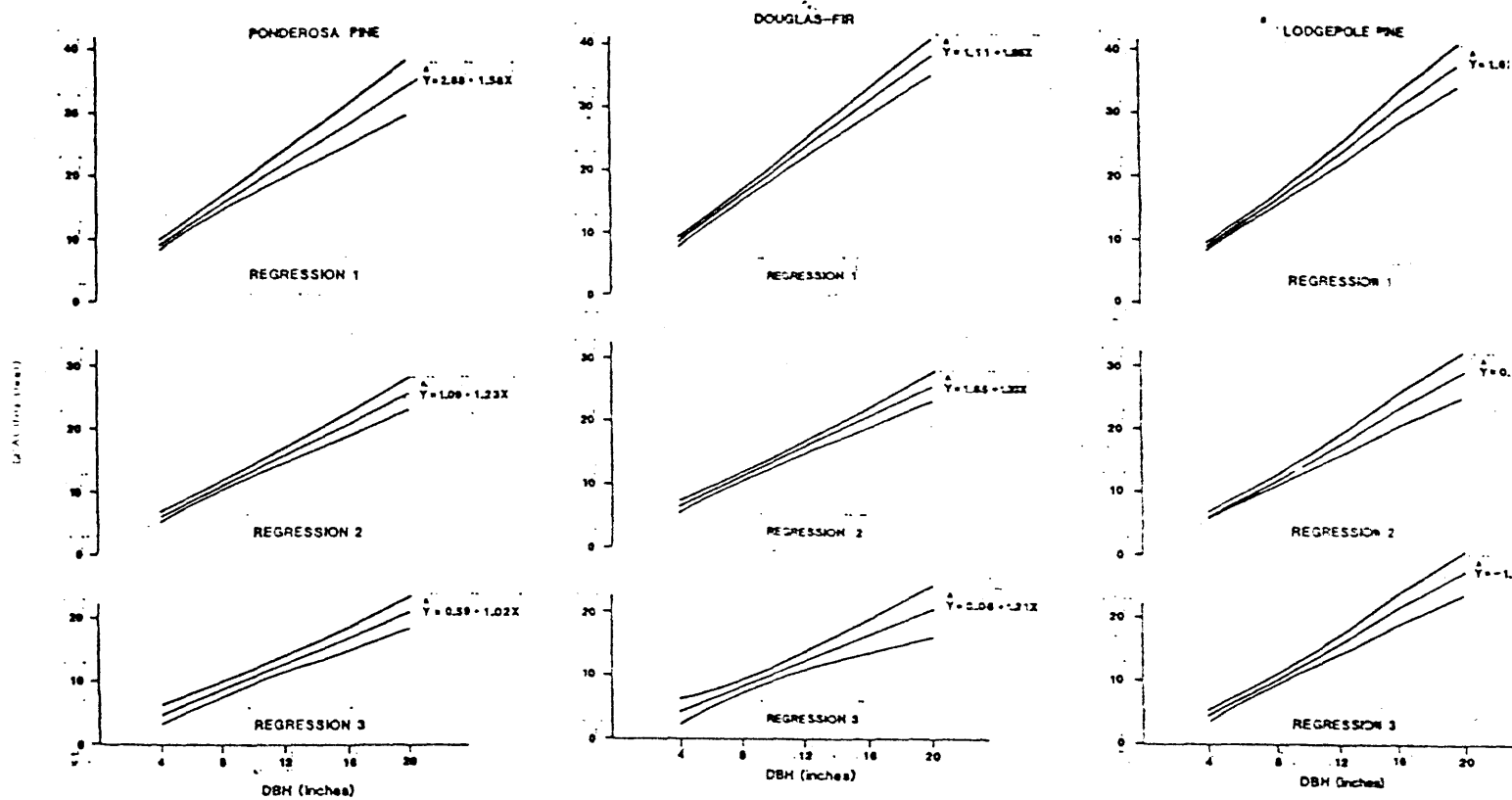


Figure 6--Confidence intervals (95%) for the spacing/DBH regressions (table 2) for ponderosa pine (figure 3), Douglas-fir (figure 4), and lodgepole pine (figure 5).

Table 1.—Mean diameter growth rates during each period and the mean dbh at the end of each growth period for open-grown trees.

Ranger district	Species	Habitat type	Average 1/ site index 100-yr base age	Number of trees in sample	Growth rate before culmination point reduction (RPI)	DBH at culmination (in.)	Growth rate between first and second reduction (RPI)	DBH at second reduction (in.)	Growth rate between second and third reduction (RPI)	DBH at third reduction (in.)	Growth rate after third reduction (RPI)
North Fork	Douglas-fir	Pame/caru-pipo	98	3	8.1	20.5	13.7	28.5	23.9	30.6	44.6
	Ponderosa pine	Pame/caru-pipo	79	5	6.6	13.6	10.9	20.1	16.8	25.8	22.1
		Pame/cage-pipo	77	3	8.8	12.6	13.7	19.2	23.0	--	--
		Pame/syal-pipo	87	3	7.6	13.2	13.7	20.0	21.6	26.1	26.8
	Average for all sites		81	-	7.5	13.2	12.4	19.8	19.8		
Salmon	Douglas-fir	Pame/feid-feid	65	4	9.2	12.8	16.3	21.9	21.2	--	--
		Pame/caru-feid and/caru-caru	75	4	7.8	16.4	10.8	26.6	17.0	33.2	29.2
	Lodgepole pine	Pame/caru-caru	74	6	7.1	9.5	11.8	--	--	--	--
Leadore	Douglas-fir	Pame/caru-caru	58	3	8.9	11.5	12.4	18.3	25.9	--	--

1/ Site Indexes (100) are from the following: Douglas-fir is from Brickell (1968) and converted to a 100 year base age, ponderosa pine is from Meyer (1938) and lodgepole pine is from Alexander (1966). These site indexes are higher than shown on the Salmon N.F. Timber Inventory for these areas. Probably because many or most of the Inventory Site Trees have had at least some competition whereas these trees have been free to grow. The Inventory Site Trees are more realistic to use for mont height projections.

Table 2--Tree spacing and d.b.h. regression equations for Douglas-fir, ponderosa pine, and lodgepole pine on the Salmon National Forest. Regression equations represent the minimum space required to achieve the maximum average growth rate.

Species	Maximum ave. growth rate rings per inch	Sample size	Range of data (inches d.b.h.)	Equations	r^2
Douglas-fir	8 ^{1/}	25	1-13	$\hat{Y} = 2.68 + 1.58X^{2/}$	0.86
	16	21	2-16	$\hat{Y} = 1.09 + 1.23X$	0.91
	32	8	4-21	$\hat{Y} = 0.59 + 1.02X$	0.96
Ponderosa pine	8 ^{3/}	36	2-14	$\hat{Y} = 1.11 + 1.85X$	0.91
	16	29	2-21	$\hat{Y} = 1.65 + 1.20X$	0.89
	30	7	6-14	$\hat{Y} = 0.08 + 1.01X$	0.92
Lodgepole pine	9	39	2-12	$\hat{Y} = 1.63 + 1.80X$	0.90
	19	37	2-11	$\hat{Y} = 0.62 + 1.39X$	0.81
	35	22	3-13	$\hat{Y} = -1.10 + 1.41X$	0.89

^{1/} This figure is further divided in figure 4 according to crown ratio. Figure 7 can also be used here.

^{2/} The independent variable, X, is the tree d.b.h. The dependent variable, Y, is tree spacing.

^{3/} This figure is further divided in figure 3 according to crown ratio. Figure 7 can also be used here.

Table 3--Equations for spacing/d.b.h. for different crown ratio groups,
Salmon National Forest, Idaho.

Species	Crown ratio	Equations	r ²
Douglas-fir	60	$\hat{Y} = 1.86 + 1.15X^{1/}$	0.85
	50	$\hat{Y} = 1.42 + 0.98X$	0.79
	40	$\hat{Y} = 0.89 + 0.94X$	0.63
	30	$\hat{Y} = 1.78 + 0.74X$	0.78
Ponderosa pine	40 & 50	$\hat{Y} = -0.27 + 1.05X$	0.90
	30	$\hat{Y} = -0.97 + 0.99X$	0.86
Lodgepole pine	50, 60 & 70	$\hat{Y} = -0.39 + 1.32X$	0.52
	30 & 40	$\hat{Y} = -1.26 + 1.26X$	0.65

^{1/} The independent variable, X is the tree DBH. The dependent variable, Y is tree spacing.

Table 4--Minimum growing space and maximum Stand Density Indices (SDI) required by 10-inch trees to attain different levels of diameter growth rates, Salmon National Forest.

	Maximum rate (first growth reduction point)	Intermediate rate (second growth reduction point) (about 50% of maximum)	Third growth reduction point (about 25% of maximum)
Douglas-fir			
Spacing SDI	19.7 110	13.8 230	10.2 420
Ponderosa pine			
Spacing SDI	18.4 130	13.3 250	10.7 380
Lodgepole pine			
Spacing SDI	19.8 110	14.6 200	12.9 260
	Tree will grow at the maximum rate until they reach 10 inches d.b.h. Some growth reduction occurs before crown closure.	Maximum production of useable timber may occur near this point - unconfirmed.	At higher densities one would expect significant competition related mortality.

Table 5--Twenty-year diameter growth on 41 ponderosa pine plots is compared to predicted growth based on crown ratio and spacing. The growth plots are located in Northern Arizona (Ronco and others 1985), Black Hills (Edminster 1988), and Central Oregon (Barrett 1982). Percent error was calculated according to $(\text{Predicted DBH} - \text{Ending DBH}) / \text{Starting DBH}$. The r squared value for Actual vs Predicted DBH is .94. See equations in figure 3.

Study area	Spacing	Ending crown ratio	Average DBH			Percent error
			Initial	Ending	Predicted	
	(ft)	(%)	(in)	(in)	(in)	(%)
Arizona	8.0	53	4.5	6.0	5.6	-6.7
Arizona	9.2	53	6.3	7.4	7.1	-4.1
Arizona	9.6	54	5.3	7.1	6.6	-7.0
Arizona	10.1	56	5.0	7.0	6.2	-11.4
Arizona	11.4	56	7.5	8.7	8.6	-1.1
Arizona	11.6	55	5.4	7.6	6.8	-10.5
Arizona	12.4	58	7.5	8.8	8.8	0.0
Arizona	13.2	59	5.4	7.8	7.3	-6.4
Arizona	14.6	58	8.2	9.7	9.5	-2.1
Arizona	17.7	62	8.7	10.7	10.4	-2.8
Arizona	18.5	59	5.5	8.8	8.0	-9.1
Arizona	26.7	66	9.5	12.4	12.4	0.0
South Dakota	8.4	59	3.9	5.0	5.2	4.0
South Dakota	9.3	54	5.1	6.6	6.4	-3.0
South Dakota	9.4	62	3.9	5.2	5.3	1.9
South Dakota	10.3	60	3.7	5.2	5.5	5.8
South Dakota	10.4	58	5.3	6.9	6.6	-4.3
South Dakota	10.7	50	6.8	7.4	8.0	8.1
South Dakota	11.6	55	6.6	7.6	7.3	2.6
South Dakota	11.6	50	7.5	8.6	8.5	0.0
South Dakota	11.7	53	5.4	7.3	6.3	-6.8
South Dakota	11.9	62	3.8	5.6	6.3	12.5
South Dakota	12.7	54	7.7	9.1	9.0	-1.1
South Dakota	13.2	55	6.8	8.0	8.0	0.0
South Dakota	13.9	60	5.8	7.9	7.9	0.0
South Dakota	14.3	67	3.6	5.7	6.5	14.0
South Dakota	14.6	62	6.4	7.9	8.2	3.8
South Dakota	14.6	54	8.0	9.5	9.2	-3.2
South Dakota	16.9	62	8.1	10.1	9.8	-3.0
South Dakota	17.3	66	5.9	8.5	8.8	3.5
South Dakota	18.2	58	6.6	8.2	9.1	11.0
South Dakota	20.0	64	3.7	5.7	6.2	8.8
South Dakota	21.1	60	8.4	10.5	10.9	3.8
South Dakota	24.6	69	5.9	8.8	8.8	0.0
South Dakota	26.1	63	6.6	9.0	9.1	1.1
South Dakota	32.5	68	9.2	12.2	12.1	-0.8
C. Oregon	6.6	57	1.9	4.9	4.9	0.0
C. Oregon	9.3	66	1.7	6.3	6.2	-1.6
C. Oregon	13.6	73	1.9	8.0	7.8	-2.5
C. Oregon	18.7	76	2.3	10.1	9.4	-6.9
C. Oregon	26.4	80	2.1	11.8	10.4	-11.9

PINYON-JUNIPER MANAGEMENT IN REGION 3

Carol J. Holland
Zone Silviculturist
Apache-Sitgreaves National Forest¹

ABSTRACT

The distribution, classification, inventory and silvical requirements of pinyon-juniper (P-J) are discussed. The two classification approaches that the Apache-Sitgreaves NF's has taken are 1) habitat typing, 2) the component approach-Terrestrial Ecosystem Survey (TES). Silvicultural systems and cutting methods are discussed for managing the pinyon-juniper woodlands. It is reasonable to presume that the silvicultural techniques that have been applied to our commercial timberlands can and should be applied to our woodland stands. This includes the managing of the woodland either under even-aged or uneven-aged silvicultural systems. Predominant cutting methods that would be most applicable, would be the single-tree selection and shelterwood cutting methods. The clearcut method has its place in managing the woodland as long as there is an alligator juniper component present.

INTRODUCTION

When you consider how extensive the pinyon-juniper (P-J) ecosystem is...17% of the land acres in Arizona is classified as P-J and 26% in New Mexico and with approximately 47 MM acres in the entire western United States, the pinyon-juniper woodland becomes a very important entity to consider for management.

The following discussion on P-J management will be narrowed down to five species that are prevalent in the Southwest. Colorado pinyon (*Pinus edulis* Engelm.), one-seed juniper (*Juniper monosperma* (Engelm.) Sarg.), Utah juniper (*J. oosterosperma* (Torr.) Little), alligator juniper (*J. deppeana* Steud.) and Rocky Mountain juniper (*J. scopulorum* Sarg.).

As extensive as the P-J woodland is, woodlands occupy radically different effective environments for plant growth. One of the primary "drivers" of vegetation

change-'climate'-is quite variable. Soils and landforms are likewise heterogeneous, but are believed to be not as influential as climate and unusual weather in controlling macro-patterns and the rate of succession (1),(2).

The woodlands occur primarily on foothills, low mountains, mesas, and plateaus at elevations from 4,000 to 8,000 feet. Within these elevations, distribution of trees will vary according to precipitation and temperature regimes in specific areas. In general, the lower elevational limits are controlled by limited soil water and upper limits by unfavorable temperatures. In some cases, both lower and upper limits of distribution are established by unfavorable temperature regimes.

The woodland has a wide variation, with differing tree species, scrub species and understory of herbaceous vegetation. Within specific stands, the P-J woodland expresses a diversity in appearance and composition that is not usually apparent from casual observation. This diversity ranges from closed canopy situations with many species or a single species, to very open stand situations. Some stands may have a very well developed understory or herbaceous cover, to others that have very little or no understory.

Stands may exist as an all-aged stand or even-aged (3). Even-aged stands characteristically occur as a result of some catastrophic event such as fire or as a result of recent management practices.

CLASSIFICATION

All in all, "Everybody knows what P-J woodlands are, but no one seems to agree where they stop (4). There has always been a need to define and classify what we call the woodland, but there is much confusion because woodland adjoins other vegetation not fitted to general concepts that, for instance, UNESCO, has used in the past. Pinyon-juniper woodlands commonly blends and inter-

¹ Presented at the 1989 National Silviculture Workshop, Petersburg, Alaska, July 10-13, 1989.

grades into such vegetation as chaparral (shrub dominated plant communities), grasslands, shrub-steppes (codominant mixtures of grasses and shrubs), evergreen woodland, and ponderosa pine or other "forest" types. The places where there is overlap between species, some people or agencies call by various names, such as vegetation woodland, while others refer to it as chaparral or grassland (4).

To address this confusion and make it more manageable, Region 3 has taken two major approaches, for ecosystem classification, which by definition must be based on and describe vegetation, soils, water and landform. First, to let vegetation indicate the ecosystem, and second to use a component approach.

This first approach is widely subscribed to by plant ecologists. It assumes that vegetation reflects the causal and interactive factors of the environment. This infers that vegetation is more measurable than climate, soils, zootic influences and the wide possibilities of interactions and combinations of causal factors (4). Plant associations have been developed for the region and have been successfully integrated into management activity decisions.

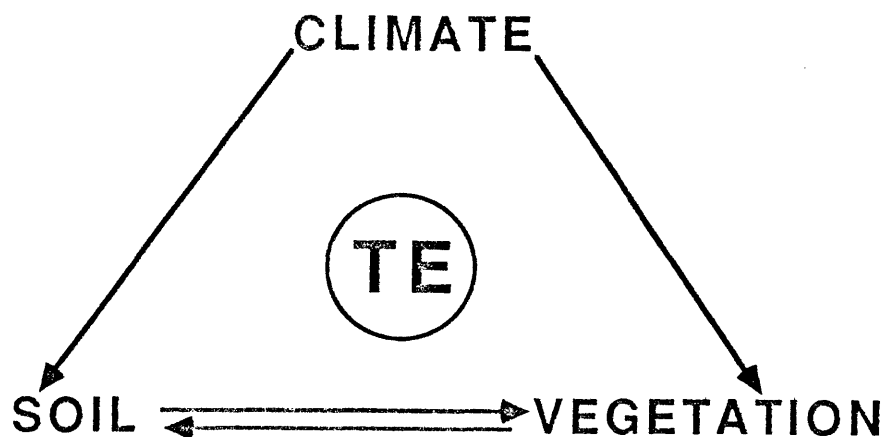
When plant associations are mapped onto the landscape

at the local scale of 1:24000, a habitat type map is produced. Habitat types draw attention to lands capable of supporting the same plant association at climax (4). These habitat types may be very homogeneous in species composition and such, but may also express a strong difference and reaction to different management practices within the same habitat type.

The Southwestern Region has published a number of habitat type guides but it is recognized that the classification of P-J at the plant association level is still incomplete. It is estimated that there may be as many as 70 plant associations and about 280 ecological sites in the Southwestern P-J woodlands (4).

The component approach that the Southwestern Region has taken to help in the classification of woodlands is the Terrestrial Ecosystem Survey (TES). There are three ecosystem components used for classification, climate, vegetation, and soils. This type of classification seems to be most useful in regional areas where vegetation has been extensively modified under various management practices...these are areas where the present vegetation or lack thereof cannot give an accurate measure of historic plant associations. Because of this, other components must be looked at...such as soils.

TERRESTRIAL ECOSYSTEM

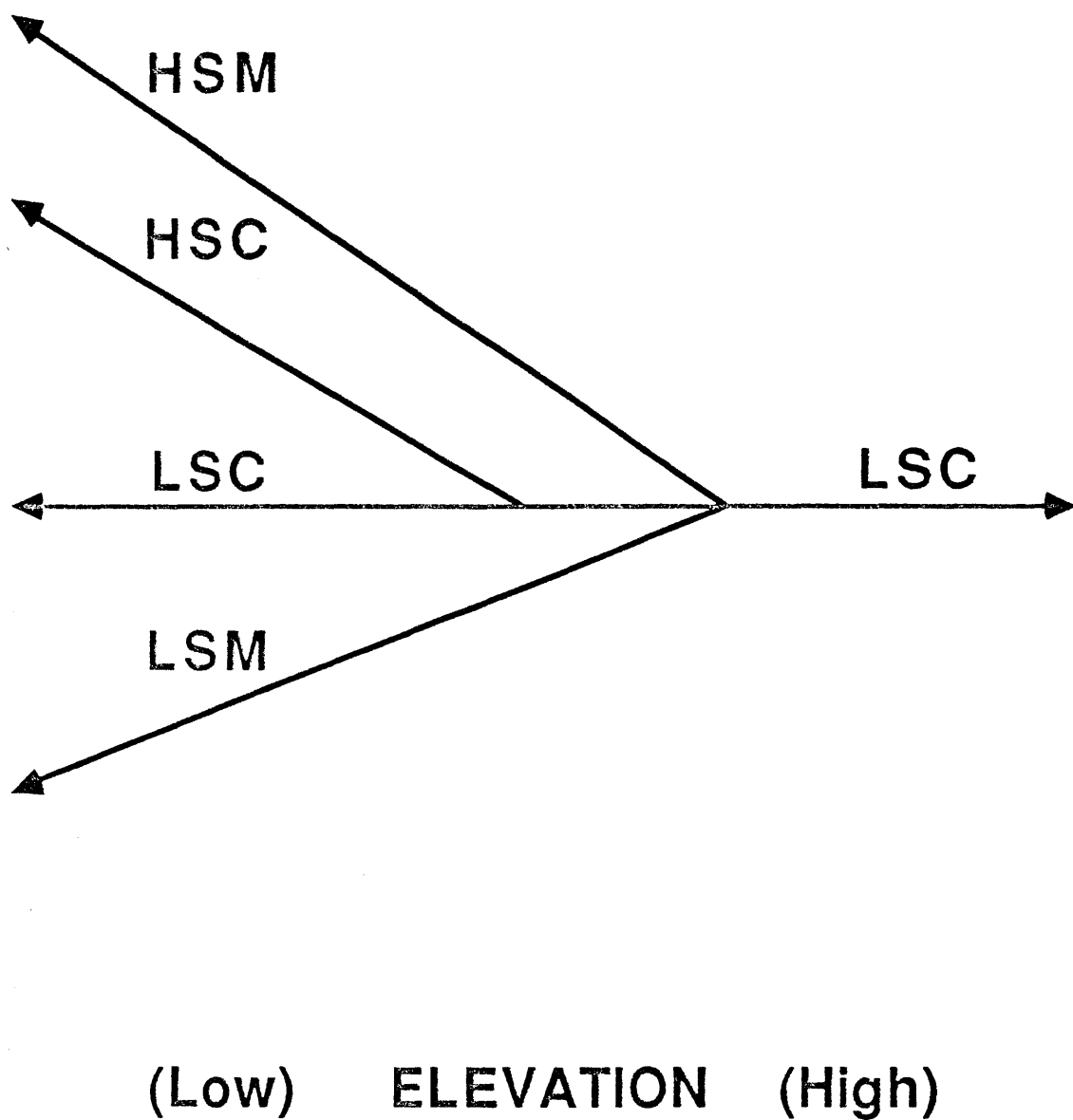


Pinyon-Juniper Management
Region 3

There are four categories of woodland climates over Arizona and New Mexico (5). These climates have been named Low Sun Cold (LSC), High Sun Cold (HSC), Low

Sun Mild (LSM), High Sun Mild (HSM)...and also have indicator species associated with them.

REGION 3 CLIMATIC GRADIENTS



Within each climatic category there are three subzones or climatic gradients, 0, -1 and +1 that reflect the local

climatic gradients from relatively warm/dry to cold/wet environments (4).

Table 1
Major Pinyon-Juniper woodland subseries
in Arizona and New Mexico

CLIMATE	ELEVATIONAL SUBZONE <u>a/</u>	DOMINANT OR CODOMINANT SPECIES <u>b/</u>
LSC	0	<i>Pinus edulis</i> , <i>Juniperus osteosperma</i> , (<i>Juniperus monosperma</i>), <i>Artemisia tridentata</i>
	-1	as above except <i>Pinus edulis</i> absent or accidental
	+1	as zero (0) above but includes <i>Quercus gambelii</i> .
HSC	0	<i>Pinus edulis</i> , <i>Juniperus monosperma</i> , (<i>J. deppeana</i>), (<i>J. osteosperma</i>)
	-1	as above except <i>Pinus edulis</i> absent or accidental
	+1	as zero (0) above but includes <i>Quercus gambelii</i> , (<i>Q. undulata</i>).
LSM	0	<i>Pinus monophylla</i> , <i>Juniperus osteosperma</i> , (<i>J. monosperma</i>), <i>Quercus turbinella</i> , <i>Arctostaphylos pungens</i>
	-1	<i>Juniperus osteosperma</i> , (<i>J. erythrocarpa</i>), (<i>J. monosperma</i>), <i>Quercus turbinella</i> , <i>Prosopis velutina</i>
	+1	as zero (0) above but includes <i>Quercus arizonica</i> , <i>Juniperus deppeana</i> .
HSM	0	<i>Pinus discolor</i> , (<i>Pinus edulis</i>), <i>Juniperus deppeana</i> , <i>Quercus grisea</i> , (<i>Q. arizonica</i>)
	-1	(<i>Juniperus deppeana</i>), (<i>J. erythrocarpa</i>), <i>Quercus emoryi</i>
	+1	As zero (0) above but includes <i>Quercus hypoleucoides</i> .

a/ 0 = typical or modal open woodlands, -1 = low elevation juniper savannas, +1 = high elevation, generally closed-canopy woodlands.

b/ Species in parentheses may or may not occur depending on geography.

Table 1 displays the major vegetation subseries in each climate and subzone. This chart is by no means complete. There will be some vegetative departures from this exhibit due to special soils and topography. It is expected that as more inventories and mapping projects are done, that there will be additional subseries described.

INVENTORY

Within the past three years the Apache-Sitgreaves N.F.'s have recently implemented their Forest Resource Inventory that incorporated not just an inventory of the commercial timber lands, but an inventory of the woodland type as well. The inventory itself consisted of stratification of the vegetation from aerial photographs, including cover type, size classes, stocking, slope, and site quality estimates and transposing them onto mylar topographic maps. The establishment of plots were distributed over a 5,000 meter grid covering the entire forest.

Where a plot fell in the commercial timber land, a regular forest inventory plot was taken, using the standard Stage II contract specifications. When a plot fell in the Pinyon-juniper, a permanent plot was established. These plots were identified and pin-pricked on aerial photos. Both reference points and witness trees were permanently marked, either on trees or rock monuments. Plot centers were established with 3/4 X 30" long angle iron sprayed with aluminum paint, and having a rock cairn at its base...the stake not being over 10 inches from ground level. On the stake, the plot number and date of establishment is stamped. I have heard that the success rate for relocating 20 year old permanent plots goes as high as 80 %...which is an excellent track record. The other 20% failure rate has been attributed to poor transcribing and inaccurate records. This supports the need to research accurate documentation.

It is fortunate for the Southwestern Region that we have a stand exam contract that is flexible enough to accomodate both timber as well as woodland species.

SILVICS OF THE PINYON-JUNIPER

The first step in understanding how to manage the P-J woodland is understanding the silvics of the species in question.

Pinyon pine (*Pinus edulis* Engelm.) has also gone by the name of Rocky Mountain pinyon, Colorado pinyon, nut pine, and two-needle pinyon.

Pinyon pine (*Pinus edulis* Engelm.) begins to bear cones around the age of 25. Maximum seed production does not occur until a tree is between 75-100 years old. Pinyon pine cones require almost three growing seasons to mature and will continue to bear cones for another 3-4 centuries (3).

Pinyons are considered to be monoecious, that is, they bear both male and female flowers on the same tree. In comparison, other pines are wind pollinated. The pinyon seed is a heavy and wingless seed, and is not adapted to wind dispersal.

Seed dissemination in pinyon happens in four ways. Gravity is one way, but is actually ineffectual. It is figured that 94-98% of the sound seed falls beneath the crown. Hydrological incidences, such as heavy downpours will move seed from beneath crowns to more open areas away from the protection of the nurse tree. Dispersal in this manner will only move seed a minimal distance, more on steeper slopes. Wind...is again very ineffectual, as mentioned before, due to the heaviness and wingless nature of the seed. Rodents...probably have an effect on the dispersal of seed but there is no supportive data concerning any caching behavior. The fourth and probably most effective manner of dispersal is from corvid birds. (13)

Four species of birds are known to eat and cache pinyon seeds: Clark's nutcracker (*Nucifraga columbiana*), pinyon jay (*Gymnorhinus cyanocephala*), scrub jay (*Aphelocoma coerulescens*), and Steller's jay (*Cyanocitta stelleri*). (13)

Vander Wall and Balda (7), studied the coadaptation of Clark's nutcracker and *P. edulis* near Flagstaff, AZ. This species can harvest seed from green cones starting in August and will cache in communal caching areas for later use. They have a sublingual pouch or expandable esophagus which may hold up to 56 seeds. They travel in flocks of 50-150 birds and can transport seed up to 7.5 miles. With this kind of caching behavior, Clark's nutcracker will tend to perpetuate existing pinyon stands, restock clear cuts, and will introduce pinyon into other habitat types, especially up into the higher elevations. The caches are usually on steep, south-facing slopes where snowmelt will occur earliest in the spring. Vander Wall and Balda (7), indicate that pinyon cones and seeds have evolved with certain morphological characteristics, such as seed color and cones that are oriented outward and upward, which tend to favor dispersal by birds. The trees benefit by having the birds disperse their seed, while the birds benefit by having a food supply during the most unproductive time of the year. In addition, Clark's nutcracker, which breeds

in late winter or early spring, uses stored pinyon seeds to obtain energy necessary for reproduction.

The pinyon jay is a slightly smaller species, usually harvests from green cones and can carry an average of 30 seeds in its sublingual pouch. It has been documented that Pinyon jays have an uncanny ability to differentiate between filled and empty or diseased seeds by using a combination of seed color, weight, and sound (by clicking the seed with their bills) (6).

Scrub jays are found in relatively dense but widely distributed populations. They harvest from open cones (15). They can carry approximately 4 seeds in their mouths for a average distance 150 feet from the crop trees (14). Scrub jays will help regenerate small areas only (3). There has not been as much data collected on the relationship of the scrub and Steller's jay and pinyon pine.

Pinyon is basically considered a shade intolerant species, but contradictorily, most seedlings are found under the canopies of trees or shrubs. The nurse tree or shrub, provides enough shade to moderate the environmental conditions of moisture and light, wind effects and solar radiation. Although pinyon seedlings are usually found in shade, literature indicates that the overstory foliage is usually not dense enough to reduce light intensities below tolerance levels for survival (8).

Junipers in the Southwest, are found both as unevenaged as well as evenaged stands. As can be surmised, most of the evenaged stands have evolved because of past fires. Stands of young juniper trees may be related to species eradication, ie: chaining, and usually are surviving advanced regeneration.

As in the pinyon, junipers have a seed that is relatively

heavy and wingless, so they would depend upon other ways to disperse themselves besides the wind.

The major methods of seed dispersal in order of importance are birds, mammals and gravity/run-off. From the literature, it is stated that the Bohemian waxwing (*Bombycilla garrul*) eat large amounts of Rocky Mountain juniper seeds as do other waxwings, robins, turkey and several jays (9). Townsend's solitaire (*Myadestes townsendi*) has also been stated as an important agent in one-seed juniper dispersal (10). Again, it is suspected that the junipers have co-evolved along with the various birds as have the pinyon, since the berries ripen at a time when other food sources are very scarce.

There are a number of mammals that depend upon the seeds for a large portion of their dietary needs and who greatly contribute to the seed dispersal. The coyote, bighorn sheep, mice, and rabbits are just a few. Domesticated animals such as cattle and especially sheep are major dispersal agents who transport the seed, trample it into the ground and who reduce vegetation competition, allowing the seeds to establish themselves (9). Unfortunately, juniper seeds have a very low germination rate due in part to their impermeable and hard seed coat, chemical (germination) inhibitors or because the embryo remains dormant (11).

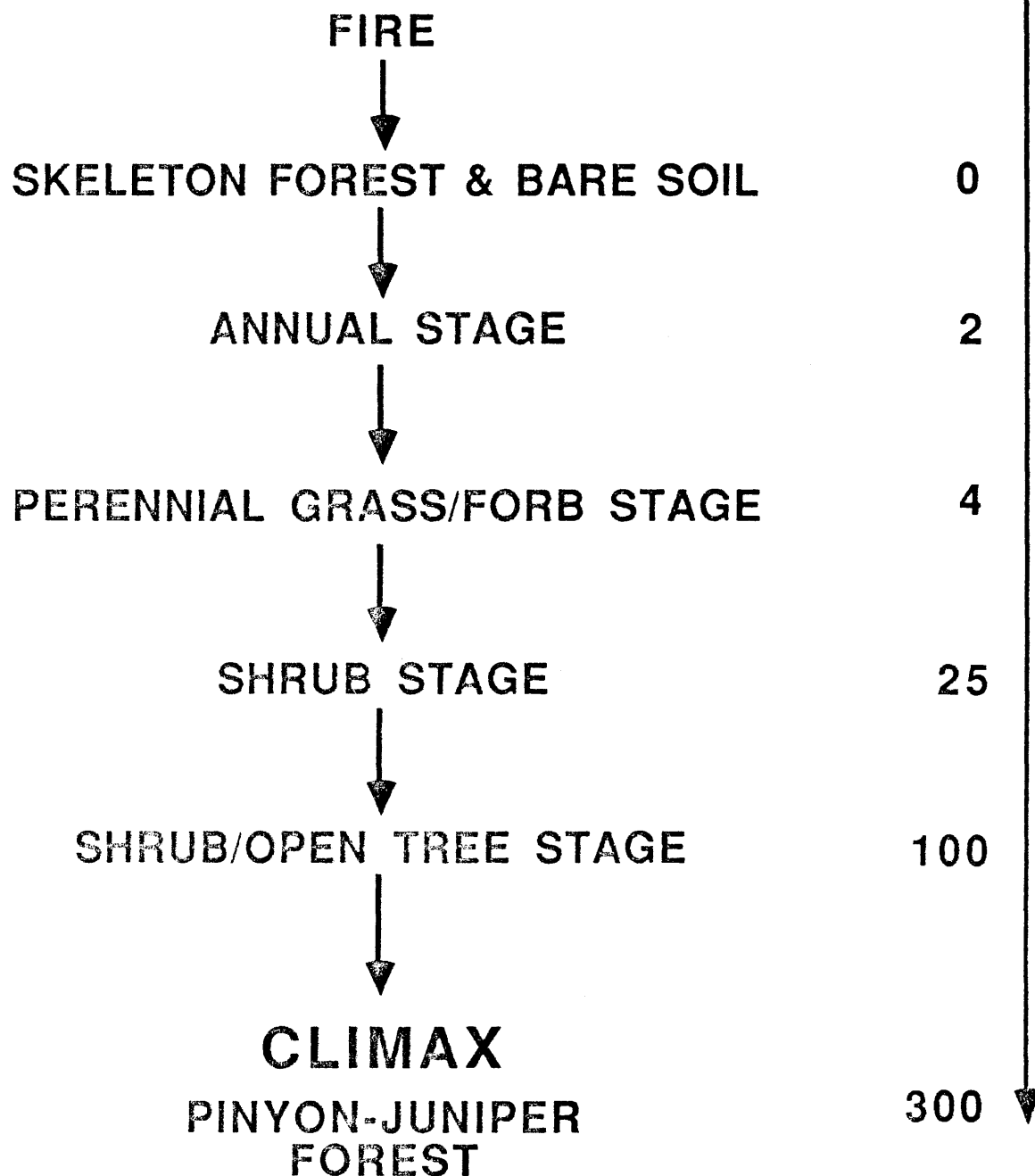
Again, as in pinyon, juniper regeneration is usually found under the canopy of other trees and bushes. They are shade intolerant but seem to need a nurse crop to minimize harsh environmental conditions.

It seems that fire is the most important natural disturbance in junipers. Junipers have a greater ecological amplitude and will invade an area first and are then followed by pinyon. Pinyon will generally replace juniper on higher sites.

CLIMAX

PINYON-JUNIPER
FOREST

IN YEARS



SILVICULTURAL MANAGEMENT SYSTEMS AND STRATEGIES

The range of various management objectives and or strategies in the pinyon-juniper woodlands is as diverse as perhaps some of the stands themselves. Not only do you have differing objectives among land owners but the needs of society also change. Broad management schemes have traditionally been of a single or primary emphasis. We have for years chained and converted thousands of acres of pinyon-juniper to grasslands to create forage. We have now moved from single-uses such as this to other woodland uses as the needs of society dictate. Alternate uses may be that of preservation, type conversions, wood production, pine nuts, wildlife habitat enhancement, visual quality, protection of watersheds, recreation, and Christmas trees.

So we are now dealing with multi-resource objectives when considering how best to manage a piece of ground.

Once our stand objectives are stated, we need to review what type of silvicultural system and subsequent cutting method to use to best achieve those objectives.

Silvicultural systems can be distinguished as either even or uneven-aged.

The cutting methods associated with the even-aged silvicultural system are clearcut, shelterwood and seed-tree.

The seed-tree cutting method removes all tree species, except for few trees (can range between 7-15 trees per acre) evenly distributed throughout the stand.

Knowing the silvical characteristics of pinyon-juniper, this cutting method is practically ruled out of consideration, due to the fact that P-J has a heavy non-winged seed which infers that seed deseminatation is limited and that P-J requires shade for germination and growth.

The group-selection method completely removes small groups of trees over the entire stand with the sizes of the groups held to an area small enough to assure that the site will be protected by the surrounding trees. The openings should be no larger than twice the average height of the mature trees in the stand. The group-selection method would seldom, if ever, be used for uneven-aged woodland stand management because it is difficult to locate and track the small groups and administer wood removal (12).

So the most appropriate Woodland Cutting Methods are as follows:

CLEARCUT CUTTING METHOD

+ This is the simplest method to apply, requires the least amount of silvicultural skill and sale preparation and administration time.

+ Relatively inexpensive per acre to implement.

+ Gets you to the grass-forb seral stage the quickest. Can manipulate size and shape.

+ In turn, increases both forage and browse for wildlife and cattle. This benefit could last up to 30 years.

+ Horizontal diversity for certain wildlife use can be created when this method is used interchangeably with other cutting methods.

- This method provides for vertical diversity.

- Tree species composition...no residual left.

- Natural regeneration is possible when there is an adequate component of alligator juniper. Sprouting will not occur with other species. Artificial regeneration is not an economical option.

- The site is exposed to direct insolation, wind and water erosion.

- May not meet visual quality objectives.

+ Prescribed burning can be used if there is adequate fine fuels to carry a fire and if you do it before the allegator juniper sprouts.

+ Most effective to control dwarf mistletoe (12).

*TWO-
STEP
SHELTER-
WOOD
CUTTING
METHOD*

0 Higher technical skills are required in prescribing and marking than in the clear cut.

0 There are higher costs in sale prep. and admin.

0 Forage and browse production is less than in the clear cut. The grass-forb stage is only present during the regeneration period.

0 Horizontal diversity can be created between stands with different ages.

0 There is some vertical diversity but is limited.

+ Have an opportunity to manipulate the stand species composition.

+ There is better control over the site conditions for regeneration. This method can take advantage of the heavy wingless seed species.

+ There is good site and soil protection due to the residual stems.

+ Generally the appearance or esthetics is more acceptable over the rotation of the stand.

- Prescribed burning is not a viable option.

+ Dwarf mistletoe can be controlled under this cutting method (12).

*SINGLE
TREE SE-
LECTION*

- This method requires the greatest skills to manage, especially in the areas of diameter distribution and proper stocking levels.

- The cost of preparing a sale and administering the removal is higher than other methods.

- This method does not bring the stand to a grass-forage stage...is basically non-existent.

- Forage for cattle and browse for wildlife is always going to be lower in this method.

- There is no horizontal diversity since the stands would be large and continuous.

+ In this method there would be maximum vertical diversity within the stand, more than any other cutting method.

+ Tree species composition can be easily manipulated.

+ This is the best method to assure regeneration within the stands. The stand would facilitate establishment and growth due to abundant shading of seedlings.

- + The site is protected from solar radiation and wind.
- + This method is desirable esthetically.
- Prescribed fire is not an option due to the nature of the stands.
- This method is least desirable and effective in controlling dwarf-mistletoe in pinyon pine (12).

CONCLUSION

These silvicultural systems and cutting methods have not been truly tested by research except in a few situations. The jury is still out regarding this. However, I believe it is reasonable to suggest that silvicultural techniques that have been applied to our commercial timberlands can indeed also be applied to woodland stands.

In choosing an appropriate silvicultural system or cutting method, the silviculturist must consider the land management objectives and the species silvical requirements as they apply to habitat conditions, regeneration, growth characteristics, shade tolerances.

We realize that more research is needed to test, substantiate or negate our assumptions concerning the management of P-J Woodland. In the Southwest, there has been an increase in research, in data collection and interpretation of that data, in order to better understand the P-J ecosystem and to better meet the needs of society.

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