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Communicating the Role of Silviculture in Managing the National Forests

Proceedings of the National Silviculture Workshop

May 19-22, 1997
Warren, Pennsylvania

Cover Photo. Stand development after the first silvicultural clearcut on the Allegheny National Forest more than seven decades ago.

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Foreword

The 1997 National Silviculture Workshop was held in Warren, Pennsylvania, and hosted by the Allegheny National Forest, Region 9, and the Northeastern Forest Experiment Station. This was the latest in a series of biennial workshops started in 1973, in Marquette, Michigan. The theme of this workshop was "Communicating the Role of Silviculture in Managing the National Forests."

The communication theme is especially timely and critical for several reasons. First, the Forest Service has been practicing good silviculture for several decades, but we have not done a good job of communicating that fact to our publics and customers. Second, the skills and capabilities of our silviculturists have often been overlooked both internally and externally. And finally, we need to communicate the importance of developing and following scientifically sound silvicultural practices as we move toward an ecological approach to the management of the national forests.

An excellent field trip to the Allegheny National Forest and the Kane Experimental Forest was hosted by Allegheny National Forest and Northeastern Station personnel. The field trip gave the participants an opportunity to observe and discuss forest research and management activities and how they might be used to demonstrate how silviculture can be used to achieve a variety of desired forest conditions.

The need for silviculturists to communicate their role and the role of silviculture in the current management of national forests is critical. This was discussed in an open forum at the workshop and a team of NFS (National Forest System) and Research people was assigned to address this need and develop a strategy to deal with it.

The Washington Office Forest Management (WO-FM) and the Forest Management Research (WO-FMR) staffs appreciate the efforts of our hosts in Pennsylvania. Special acknowledgment is made to Chris Nowak, Jim Redding, Susan Stout, Wendy Jo Snavley, and Kathy Sweeney, Northeastern Station; Robert White, Steve Wingate, and Lois Demarco, Allegheny National Forest; and Monty Maldonado, Eastern Region, for their leadership and support in planning, arranging, and hosting the workshop. Also commended are the speakers for their excellent presentations; the poster presenters; the moderators who led the sessions; the 130 participants from Research and NFS from all over the country; and the special guests who participated in the workshop.

Dennis Murphy
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Opening Remarks: Welcome to the Allegheny NationalForest; but will we be here 10 years from now?

John E. Palmer[1]

Abstract.—In our day-to-day struggles, we must keep our eyes on what is going on. The bottomline questions are, will we be harvesting timber 10 years from now, or will the Forest Service as an agency even exist 10 years from now? The author is not optimistic, but still holds some hope. That hope is in silviculturists and other who are willing to step forward and speak out.

WELCOME

How many of you have been to the Allegheny National Forest (ANF) before? Welcome back. The rest of you are in for a treat. Like all Forest Supervisors, I enjoy bragging on the Forest and its people. I will share a little about the culture of the ANF, some unique features, and a little about the theme "communications."

CULTURE

The culture of ANF has undergone some major changes since 1988 when it moved to a unified approach. In particular, implmentation of the unified budget process has been a key to breaking down barriers and eliciting employees in decision-making through program champions. This has worked very effectively for us.

The Allegheny is the most intensively-utilized Forest I have ever worked on or seen. Unlike forests in the west, we use natural regeneration; we use herbicide; 93 percent of the Forest subsurface is privately-owned; landlines are by meets and bounds. The ANF is within a day's drive of 1/3 of the population of the U.S. and 1/2 the population of Canada. Our forest health situation is compounded with deer pressure, unprecedented defoliation, topped with droughts, open winters, and windstorms, and some of the highest levels of acid deposition in the country.

We have excellent relationships with Research, S&PF, State agencies; good relations with industries; improving relations with local communities; excellent partnerships with a number of conservation organizations and universities; good working relations with elected officials. Relations with some environmental groups is not as good as desired, which brings me to the theme - Communications.

COMMUNICATIONS

The questions I ask are, will we be harvesting timber products on the Allegheny National Forest 10 years from now? Will the Forest Service exist 10 years from now? I am not very optimistic, as I believe the answer to both is "no," but it does not have to be.

What role does the silviculturist have in communications? First, just out of curiosity, how many of you are practicing silviculturists? How many of you think you have the greatest job in the FS?

Silviculturists have one of the toughest, most challenging jobs in the world for two reasons: 1) You, as silviculturists, write prescriptions that determine the destiny of the future forests - an awesome responsibility; and 2) you turn beautiful, living organisms into stumps and then must explain that this does not harm the environment and is actually good for society.

Allow me to set up a picture in your mind to help illustrate the second reason. Most of us have a favorite tree or species. Now, take a moment to picture that tree or that perfect specimen - magnificent isn't it? Now picture this tree as a stump and you standing in front of a crowd explaining why changing this beautiful, living organism into a stump doesn't harm the environment and is actually good for society.

Think about this for a moment. The public is relying on you, one person, to write a prescription that sets the destiny of future forests by turning trees into stumps. It is indeed one of the toughest jobs in the world.

Take a moment to reflect on the following statement. Trees can be safely harvested from your National Forest without harming the environment. How many of you think this is true - show of hands? How many think this is false? How many are uncertain?

Can you say trees are, not can be, but are safely harvested from your National Forest without harming the environment? Can you say that?

Hang on to those thoughts and your uncertainty, these are important.

I will read to you something that came out about 50 years ago that may sound a little familiar to you.

"The other day I was lying on the sofa listening to a symphony and thinking what a grand and glorious world this is with nothing to worry about when, as it closed, some bull-voiced gentleman began to shout that Niagara Falls was about to be destroyed by power companies. In two minutes, he had my nerves on edge and my hair on end, aghast at the frightful catastrophe. According to his picture of it, the Falls will soon be a mere trickle, and the rapids below a brook so stagnant it will breed mosquitoes. As a honeymoon resort, it will be a total loss and, as a result, the marriage rate will go down, the birth rate will drop, and the American people will soon be a vanished breed, on their way to join the ichthyosaurus and the dodo."

[1]Forest Supervisor, Allegheny National Forest, U.S. Department of Agriculture, Forest Service, Warren, PA.

Effective! He painted a picture of something no one wants based on the uncertainties that most people would legitimately harbor about such a project, and, without saying it, grabbing at their lack of trust for big business, or in our case, big government. He brought up some legitimate concerns about water flows, the value of Niagara as a national asset, and the aesthetics for honeymooners — key ingredients to environmentalists' effectiveness with people/media. They use symbolism, uncertainty, and trust - or lack thereof.

What do you think happened to the hydroelectric project? How many of you have been to Niagara Falls? How many of you have noticed a hydroelectric plant? It is there and very unobtrusive. What side is it on? Canadian! What if that had been between us and another country not as prepared as Canada? What would the result have been? Are we prepared to export our environmental concerns to nations that are not as prepared as is the United States? We will do just that by allowing our timber program to diminish to nothing. We have a responsibility to communicate, proactively, the importance of vegetative management on National Forests to society.

We are a nation built on our resources. We are a nation built on our people. Are we prepared to say we are a nation built on other nations' resources, other nations' people, other nations' money, and other nations' environments? Is this environmental imperialism?

Why is it important that we speak out proactively? We supply important products that fulfill a demand, a demand that will be satisfied by other nations—nations not as prepared with strong environmental laws, sufficient numbers of highly-skilled people and a wealth of technical knowledge. We, the Forest Service, also play a critical role in providing answers on how to manage resources within the capabilities of the ecosystem. We provide the answers to private landowners, to other public land managers and to other nations. We should export our knowledge, not our environmental concerns.

Environmentalists are forever examining what we don't know—the glass half empty, the uncertainties of our work. They actively voice the uncertainty to the public and then add their own dramatic outcomes (symbolism) - birth rates drop, Americans a vanishing breed!

What is our typical response? Do we debate such issues in the media, the media that the environmentalist so readily use? No. We generally respond by stating what we DO know. By stating what we do know, do we address the uncertainty? Do we address the issues raised? Do we adequately address the dramatic outcomes raised by others? No, not usually.

It is time we were proactive in providing the public the questions we do not have the answers to, including what we professionally expect the result to be with the knowledge we have today. But we must take it one step further and tell the public what we are doing to answer the unknown, to test hypotheses, and monitor and share the results.

Do you have questions about what you are doing? Do you know all the answers? Do you share your uncertainty openly with the public?

How many of you, when writing prescriptions, thinking about ecosystem management, biodiversity, fragmentation and the like, and have unanswered questions, uncertainties or doubts about the results that our current breadth of knowledge does not answer? Do you feel free within our organization, the Forest Service, to voice your questions, your uncertainties openly? Do you feel you are adequately responding to your uncertainties? Are there questions you have that you never voice or dare put into an environmental assessment (EA)?

We must be proactive. We must be the first, I repeat, the first to share our uncertainties, our questions. Let opponents play off of our words, our symbols. We will always be in a losing position playing off their words and their symbols.

Put the uncertainties in EA's. We must be the first to share the probable results and be willing to monitor and share the final outcome. And we must share what we are doing to fill the knowledge gaps, to increase our breadth of knowledge. If we are truly top notch stewards, top notch professionals, as I believe we are, then we are constantly seeking answers to our questions. That is a big part of why you are here this week - you are here to seek and share knowledge.

The key ingredients of our message must contain uncertainty, symbolism and trust. The symbols will be you, the professional, providing your judgement based on science and experience, and it will be a healthy forest environment that is serving the public. Trust would be approached in two ways. Big government may never be trusted, but you individually, as a person and as a professional, will be. The other way is through proof that comes from research, monitoring, operating with an open book, and a collaborative approach to solving uncertainties.

In closing, can you explain why turning a beautiful, living organism - a tree - into a stump is good for society? Are you ready to tackle your responsibility to do just that? Are you ready to display and discuss our, your, uncertainties, and the probable results, as well as what monitoring tells us about the outcomes? Are you ready to seek answers to your uncertainties? Are you ready to share your knowledge with others? These are the questions I hope you will ask yourself - this week and beyond. You are the symbol, you are the trust - use it wisely and proactively! Have a good week!

Communicating Silviculture: Values and Benefits for the New Millennium

Robert F. Powers and Philip S. Aune[1]

Abstract.—Forests have been tied to social progress since the dawn of agriculture 10 thousand years ago. Silviculture, the oldest application of ecological principles, contains all the skills needed to produce forests with the myriad conditions valued by modern society. Historically, we have been success-makers. Yet, our profession faces a crisis. Often we are seen as tree killers, more concerned with timber harvests than with managing forests for multiple uses. Perceptions trace to critical rhetoric by those who are unusually effective communicators. Silviculturists have not responded effectively. We tend to be "doers, not sayers," but we must break this mold. We stand at the brink between the demise of our profession and a chance to establish our proper place at the table of wise forest management. Moving positively demands committment to professional renewal and more effective ways of communicating our art. Avenues vary from more effective writing, through one-on-one mentoring and outreach to other disciplines, to involvement in educational programs with a broad ripple effect.

INTRODUCTION

Do silviculturists have a communication problem? Yes. But an ironical indictment since forests and their management have been central to human progress for 10,000 years. "Ecology" was coined by Ernst Haeckel in 1866, but silvicultural concepts clearly predate him. Indeed, silviculture is the oldest application of ecological principles. Primitive silviculture probably was born of the need to protect and restore degraded land. It may trace to the Chou Dynasty (1127-255 B.C.) and the creation of the world's first forest service following 1,500 years of forest exploitation (Hermann 1976). Silviculture was practiced in the time of the Caesars when trees were planted to commemorate temples and to provide the Roman landscape with respite from the Mediterranean midday sun (Sereni 1974). Silviculture was known to Pliny who, in the first century A.D., cautioned that planting should not occur during winds or high rainfall (Tkatchenko 1930). The Austrian forester Cieslar voiced the same conclusion at the close of the 19th century (Tkatchenko 1930), an early hint of a communication problem emerging among silviculturists.

In Europe, artificial reforestation dates to 1368, when the city of Nuremberg seeded several hundred hectares of burned lands to pine, spruce and fir (Toumey and Korstian 1942). Increasingly, natural forests were felled not only for conversion to agriculture, but also to fuel the smelting of metals for a fledgling industrial society. Pine and spruce were planted throughout much of Europe and management achieved a high level of intensity by the close of the 19th century. But the silvicultural sophistication practiced in the groomed forests of Europe was not appropriate for the wilderness forests of America. Here, silvicultural principles had to be rediscovered and adjusted for a new land. As Pinchot stated in 1947: "One of our first jobs was to go and find out about what we named the "Silvics" of our trees...we had to learn that we might practice."

CONCEPTS AND PURPOSE

Evolving Viewpoints

Blasphemous though it seems to some, silviculture attempts to improve upon nature. In 1917, the Finnish Forestry Institute was established with the expressed purpose of overriding the prevailing attitude that "forests take care of themselves" (Finnish Forest Association, 1997). Hawley (1946) admonished those who took a "hands-off, leave-it-to-nature" approach as short-sighted. He advocated *active* silviculture, one employing the science of silvics within economic constraints to meet the aims of the forest owner.

Views on the purpose of silviculture have evolved throughout this century. Today we see our profession as the means by which forests are managed to best fulfill the objectives of the owner and our governing society (Smith et al. 1997). Historically, our view was not so expansive, and our critics seem locked on our past positions. Toumey and Korstian (1947), echoing the views of such early foresters as Fernow, described the main goal of silviculture as the continuous production of wood crops. Bergoffen (1949) said that silviculture was analogous to the culturing of food crops. Baker (1950) agreed that the primary purpose of silviculture was timber crop production. But he recognized that small areas might be managed in "specialized and unusual ways" to favor other "incidental" values, and this marked an important conceptual shift.

Silviculture continued to focus on timber production through the 1950's, but other goals were emerging. A new silviculture was evolving where wood growth might have low priority, or none at all (Smith et al. 1962). By the close of the seventies, Americans expected sustained wood production to be in harmony with increases in high quality water, wildlife, recreation, and aesthetics (Daniel et al. 1979).

Obscuring the Obvious

Changing social views raise basic questions about the compatibility of multiple objectives. This has not precipitated scholarly debate so much as tension, confrontation, demand for greater public involvement, and burgeoning increases in federal and state regulation. Anticipating this, Daniel et al. (1979) called for a new generation of silviculturists who not only are knowledgable, versatile, and able to predict the likely outcomes from alternative stand treatments, but who can prescribe activities meeting physiological, ecological,

[1]Science Team Leader and Program Manager, respectively, USDA Forest Service, Pacific Southwest Research Station, Redding, CA.

managerial, and social constraints, as well. They conclude that "we are surely entering the most challenging and stimulating period in forestry."

Silviculturists must be conversant and integrative in such fields as botany, cartography, economics, engineering, entomology, genetics, geography, meteorology, plant pathology, plant physiology, soil science, and wildlife biology. Surely this is a time for us to shine as applied ecologists. Yet, the opposite is true. Silviculturists seem dismissed as irrelevant or distrusted by planners, policy makers and the public. In contrast, ecologists have drawn center stage in matters of scientific expertise. Why is this so? Bolstered by heady successes in the political action years of the 1960's and 1970's, ecologists seem ready and willing to move from their own realm of expertise to those where they bear little or no authority (Peters 1995). Papers published in ecological journals often show a naivete of common forestry knowledge and a remarkable ignorance of forestry literature. Often their science is based on natural, relatively undisturbed ecosystems where cause-and-effect relations can only be surmised. Consequently, their ability to predict how forest ecosystems respond to active management is flawed. Trained in observational science more than hypothesis testing, ecologists continue to ask traditional questions, elaborate their answers, refine their approaches, and express their opinions with no real danger of finishing their research (Peters 1995). While this makes good press—and often influences policy makers—it does little to advance our knowledge of sound forest management.

Why has silviculture slipped from grace? Why have silviculturists not pospered, given the issues we face? Perhaps we're poor communicators. As Heinrich Cotta explained in 1816, "the forester who practices much, writes but little and he who writes much, practices little" (Baker 1946). Silviculturists are "doers," not "sayers." Most of our reward comes from producing a forest that meets a manager's objectives, not from conversing with people. And in the case of the U.S. Forest Service, perhaps it's due partly to agency policy that scientists and practitioners do not take positions on matters of policy. Instead, we're asked to avoid advocacy and to limit our input to the reporting of facts and the likely consequences of choices. This seems sensible enough, provided that questions are asked of us by decision makers. Increasingly, they are not.

One of silviculture's greatest hurdles is to get forest managers and society to define their wants and needs clearly (Smith et al. 1997). Another is to get someone to listen to what we might offer. Silviculturists are bypassed in the decision-making process because of old notions (perpetuated by intransigence) that we're only concerned with cutting trees. Sound prescriptions are seen as transparent excuses for harvesting. Reid (1983) joked that "silviculture is the science of turning trees into silver" and that sustained yield "is a forest management system designed to generate a steady flow of money until all the trees in the forest are gone" (Reid 1983). Humorous barbs, perhaps—but barbs tipped with poison. Repeated, clever slogans catch the public's fancy, affect attitudes, and shape public policy. Pseudoscientific publications sway public opinion and the attitudes of policy makers through either gentle persuasion (Maser 1988) or shock (Devall 1993). Such messages are powerful because they impact our feelings. Meanwhile, we are restricted to the reporting of facts. As Mark Twain aptly observed, "A lie can speed half-way around the world while truth is still putting on its shoes."

MEETING THE CHALLENGE

We're faced with the charge of reversing the prevailing notion that silviculturists "just want to cut trees," that our interests are limited to the production of timber crops and to detecting the culmination of mean annual increment. Some have stepped forward. Gustafson and Crow (1996) show how silvicultural innovation can address multiple objectives. Even- and uneven-age management systems were contrasted by melding silvicultural knowledge of stand dynamics to spatial analysis of forest structure for a period spanning 150 years. The result was a visual means for comparing alternatives relative to forest edge, opening size, age class distributions, and commodity flow. The value of this to wildlife managers and recreation planners is obvious. Another example of silvicultural innovation is in the field of restoration forestry. Figure 1 shows how careful silvicultural skills have converted a warm, eutrophic stream in an overgrazed pasture to a productive riparian ecosystem in a single decade (Williams et al. 1997). In a short span, silviculturists have transformed a degrading landscape into one with multiple, sustainable values. Silvicultural applications such as these speak powerfully of potential solutions to land management problems. But they may not speak loudly enough.

The Art of Communicating

Most of us prefer traditional ways of communicating and practicing our profession. Now we call on you to break beyond the comfortable confines of our professional circles. And why not? Our knowledge rests on a foundation of the basic natural and social sciences. We are the best integrators of scientific knowledge in the forestry field. We understand the dynamism of forest ecosystems and how they respond to treatment. We are the arm of biological technology that carries ecosystem management into action (Smith et al. 1997). This must be communicated in widening circles. Failure spells death for our profession. It means that healthy, resilient forests will not be passed to future generations.

We believe that silviculturists will face the challenge successfully. But success demands commitment, sacrifice, encouragement, reinforcement, and outreach. If silviculturists are to be seen as "success makers," we must meet the challenge on multiple fronts.

Forest resource issues carry emotional impacts, and our playing field is not level with that of professional communicators. For example, "Majesty and Tragedy: The Sierra in Peril" (Knudson 1991), serialized in a major California newspaper, earned its author a Pulitzer Prize. The title was riveting, and heralded a good discussion of land use issues spiced with provocative, powerful references to John

A

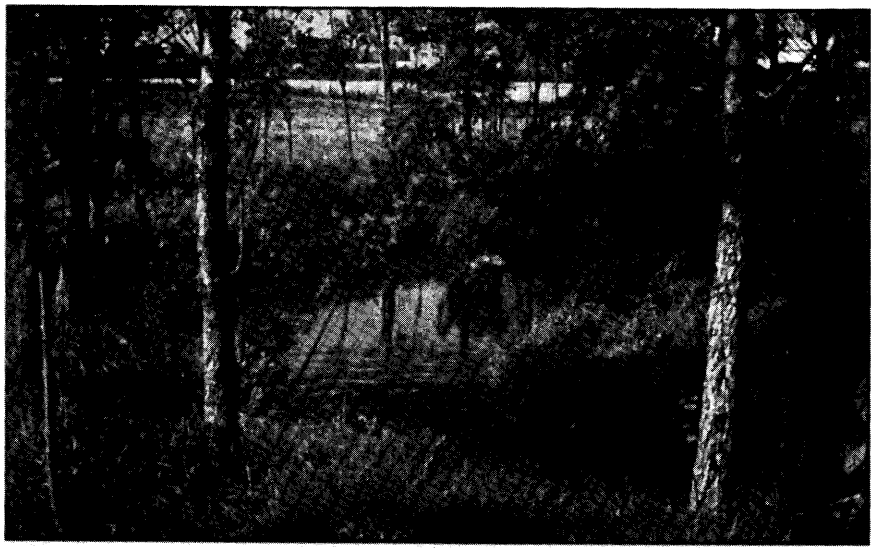

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Figure 1.—Washington Creek, southern Ontario, Canada. (A) As it was prior to rehabilitation in 1985; (B) in 1989 after reforestation with hybrid poplar, maple, and alder and a subsequent biomass thinning; (C) in 1996. Note inputs of large woody debris to the stream. Courtesy of Andrew M. Gordon as modified from Williams et al. (1997).

Figure 2.—New phrases with nebulous meaning compound the communication problem.

Muir's "Range of Light," Brazilian rain forests, Nebuchadnezzar and the cedars of Lebanon, monuments to God, eroding slopes, and mercury-laden mine wastes polluting the water supplies of greater California. Attorneys were quoted on their ecological views. Laced with value-ridden terms like "deforestation," "corn-row forestry," and "clearcut war zones," this publication painted a bleak picture of silviculture in general, and the Forest Service in particular. Literally, such prose sells papers. Scholarly, factual, voluminous reports with such titles as, *Status of the Sierra Nevada. Volume I—Assessment Summaries and Management Strategies. Sierra Nevada Ecosystem Project Final Report to Congress*, can hardly compete for the attention of an uninformed public. We are quick to holler "foul!" when issues are misrepresented in the popular press. But we seem ignorant of ways to improve our own plight. Now this must change.

Communicating with society demands a clear and concise message. But clarity in thought and speech seems blurred by the tumble of wondrous phrases seemingly sanctified beneath the cloak of "ecosystem management" (figure 2). They surface commonly in planning sessions, in discussions with other professionals, and with the public. Despite their veneer of enlightened concepts, usually they convey more fog than clarity. Collectively, we call them "ecobabble." Probably, we have contributed to them.

Some ecobabble phrases, such as "historic range of variability" and "universal fragmentation index" are at least quantitative. They can be described and discussed in a way that conveys their meaning to others. But phrases like "healthy forests," "ancient forests," and "biological legacies" are more subjective. They have a sizable impact on the senses, but their meaning is obscure. We have our own silvicultural jargon, but our terms have clear definitions (Ford-Robertson 1971, Smith et al. 1997). We need a common language. Repackaging old silvicultural terms and concepts into ecobabble does not elevate the stature of our profession. Communication is give-and-take between plain speaking and active listening. Let's say what we mean.

Forest ecosystem management seems a magnet for ecobabble, but we do not impugn the concept. Ecosystem management is a worthy goal, and tomes have been written in ways that appeal viscerally as well as intellectually (Drengson and Taylor 1997). But despite its heralding as a "new paradigm," the concept is familiar to silviculturists. Ecosystem management depends on silvicultural solutions to forest management problems based on careful analysis of the ecological factors involved. This is our traditional arena. Let's reclaim it.

Communication is not only oral. Scientific publication is our major way of communicating silvicultural advances. Yet,

many authors choose a writing style that is meant more to convince reviewers than to entice readers. As Janzen (1996) points out, scientific papers tend to list from the mass of data meant to sway peers. Remaining verbiage then is spent in drawing logical but cautiously conservative conclusions. This pattern is a natural product of the review process by which authors are scolded, prodded, sometimes coerced by their peers to reorganize their writing into a standard mold that is stilted and dry. While lending some assurance that results are valid, the product often seems blunted by the need to placate reviewers. Most scientists admit that rewards are tied largely to numbers of published papers and less so to their quality. But as Gregory (1992) has observed, "Scientists should be judged according to how many times their work is *read*, not cited."

Authors of silvicultural tracts could inject at least *some* personality into their writings. Tradition suggests that personality takes a backseat in scientific prose. Writers fall into passive voice and third-person references with the vague notion that this somehow portrays objectivity. More likely, it means that the reader may be bored to distraction. Writing is "a personal transaction between two people, conducted on paper, and the transaction will go well to the extent that it retains its humanity" (Zinsser 1994). Jansen (1996) offers several suggestions for transfusing life into scientific writing—among them, the willingness to speculate beyond the immediate limits of the data. Careful, measured speculation can be provocative enough to trigger the next level of research. Watson and Crick (1953) offer a classic example. Their landmark DNA paper concluded with this elegant, understated speculation: "It has not escaped our notice that the specific pairing we have postulated immediately suggests a possible copying mechanism for the genetic material."

Continuing Education

During the early seventies, the Bolle Report (1970) criticized the U.S. Forest Service for timber harvesting practices. Along with internal recommendations, this launched the Forest Service Silvicultural Certification Program. Keystones included continuing education requirements and demonstrated proficiency. The Society of American Foresters (1977) saw a similar need, and continuing education became a priority national program. Professional renewal through certification, recertification, and program upgrading is absolutely central to maintaining silvicultural excellence. This program is one of the proudest professional accomplishments of the Forest Service. Even with reduced budgets, education must be sustained. Those from other disciplines should participate not only as instructors, but as students. It keeps us on the leading edge. It makes our profession relevant to others.

Mentoring

Forest Service ranks are shrinking and so is our community of seasoned silviculturists. Our silviculturists still are among the world's best, but trends are discouraging. Job openings are scarce. Where they do occur, the pool of qualified applicants is small. Student enrollments in other forestry fields are stable or slightly up, but both undergraduate and graduate enrollments in forest management have fallen heavily in the nineties. Fewer are being trained with the breadth of skills described by Daniel et al. (1979). Thus, we have a compelling need to pass our knowledge on to others—including those in other fields such as wildlife biology, soil science, and ecology—disciplines that participate in the planning process but lack our peculiar mix of skills. One-on-one involvement is the most effective communication of all. Of course, willingness on our part is only half the equation. The other half requires someone receptive. Mentoring isn't for everyone, but we should try.

Professional Outreach

We must be *visible* in our profession and in the educational activities it sponsors. But let's not stop there. Let's consider professional societies other than our own. Let's be active ambassadors to other groups, raising our profile in forest ecosystem management. We must break the comfortable mold of "just talking to each other." Yet, we must be careful not to squander our energies on "professional adversaries"—those who delight in not reaching accords on matters of forest management. We must extend ourselves to others of good will. We need to make contact, communicate clearly, establish trust.

Silviculturists can be catalysts for meetings that unite, rather than divide. Recently, several agencies co-sponsored a symposium in California entitled, "Whose Watershed Is It?" Watersheds are good rallying points because they're tangible, suggest multiple values, and have a clear silvicultural connection. Yet, watershed values are weighed differently by different interests. A good first step toward bridging differences is to find common ground through a structured symposium. From this, a dialogue begins.

Teaching the Teachers

Educational investments create the widest ripples, and the sooner they're made, the better. But forestry issues rarely surface in primary education. Today's students, however, will become tomorrow's adults, men and women faced with making choices on forestry issues. How informed will they be? Will issues be judged objectively? Or will attitudes be forged early by emotionally slanted rhetoric? Judging from some textbook material, we should be worried.

For instance, in its discussion of Pacific Coast forests, *Environmental Science* (Cunningham and Saigo1997) states the following: "California redwood, the largest trees in the world and the largest organisms of any kind known to have ever existed...were distributed over much of the Washington, Oregon, and California coasts, but their distribution has been greatly reduced by logging without regard to sustainable yield or restoration." And later, "At these rates (of logging), the only remaining ancient forests in North America in 50 years will be a fringe around the base of the mountains in a few national parks." The authors seemed to have sidestepped Pleistocene glaciation, Holocene plant

migration, and California's Forest Practices Act (one of the strongest in the nation). Apparently, they also dismiss the "ancient forests" in wilderness areas (which now exceed the land areas of Ireland, Italy, and Israel combined), as well those along wild and scenic rivers, and in research natural areas, state parks, special use areas, and myriad other forests where harvesting is precluded.

Of course, forestry issues are just symptomatic of a larger problem. Moore (1993), appalled by the lack of scientific literacy in our nation, called for a revolution in teaching biology by revising K-16 grade curricula. Science and technology would be emphasized in the teaching of other skills. "We can no longer rely on a single elementary classroom teacher to teach everything," he stated. "Special science teachers will have to be educated."

We agree with the principle of "teaching the teachers" in matters of forest management. The most effective program we've seen is called "FIT" (Forestry Institute for Teachers), which was born of concerns that school children (and future voters) were getting an unbalanced view of forestry activities. FIT was a Northern California Society of American Foresters (1993) concept, but support followed quickly from county superintendents of education and the University of California Cooperative Extension. FIT's objective is to provide K-12 teachers with the knowledge and skills needed to objectively and effectively teach students about forest ecology and forest management practices. Its mechanism is summer training, combining classroom and field exercises. Its aim is for each educator who passes through the FIT program to spread new knowledge to waves of students, who in turn will fan throughout society with better understanding of forestry issues and practices.

Specifically, FIT brings teachers from both rural and urban settings together with natural resource and teaching specialists for one week in a field classroom. Each session accommodates 45 teachers who are provided a basic college-level course in the physical, biological, and ecological concepts of forestry. Assisted by curriculum specialists and materials from "Project Learning Tree" and "Project Wild," they develop K-12 courses for the following school year. Meals, lodging, and materials are provided, as well as a $300 stipend per teacher once a forestry related course is created for their classroom. Attendees also earn 3 units of graduate credit from a local university. More than 500 teachers have passed through FIT, but such grassroot programs will not be successful without knowledgeable, committed volunteers.

SUMMARY

Our task is to convince the doubters that silviculturists are not "killers of trees." Rather, that silviculture is the sole means by which forests are managed for the purposes of meeting society's needs. By stepping beyond the comfort zone of "talking to each other" we will be rewarded with a restored image of our profession and a more objective and informed public. Communication is the key. Effective communication is a creative art requiring clarity in expressing our ideas and receiving those of others. Avenues include better writing, personal mentoring, breaking beyond our professional boundaries, and committing our talent to educational efforts—especially those that "teach the teachers." The future of "applied forest ecology" depends on us.

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Silviculture: What Is It Like, and Where Have We Journeyed?

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Abstract.—The philosophy of ecosystem management calls for a new way of doing business. It represents an evolution of thinking and acting that began during the era of dominant use, and continued through the time of multiple use. As such, ecosystem management represents a maturing of thought about silviculture and other aspects of natural resources management and use. It stresses creating and maintaining a predetermined set of ecosystem conditions that serve well-defined objectives. This places a new emphasis on silviculture, but will not require a new silviculture. Rather, it means applying silvicultural knowledge and experience in new and unique ways to address new sets of objectives and opportunities.

A TRANSITION, NOT A SUDDEN CHANGE

I have been puzzled at times over the past few years with the oft-heard phrase *paradigm shift.* At times it comes across as a statement suggesting that we try something new .... some radically different way of thinking and acting. It has often been heard as a condemnation of traditional ways, and a message about intellectual inertia and inflexibility. In fact, some provocateurs have approached the philosophy of ecosystem management in that way, implying that we should cast off past ways and put on new and different technical vestments as we prepare for the future. They suggest that the old proved bad, and ecosystem management at last will make it all good.

In many ways, such an argument upsets us. It really says, "You failed! You messed up, so now get it right!" And this happened with the initial statements by some critics of what the US Forest Service has called *new perspectives* in forestry, and more recently *ecosystem management.* In fact, upon hearing the call for a new way of doing business many of us have reacted with self-justification responses. After all, hadn't we entered the ecosystem management era with a wonderfully dynamic and bountiful forest that spread extensively across the nation to the east and west of the prairie? Hadn't the area of forest cover actually increased, bringing American society greater access to the many values that we ascribe to forested lands? Don't we even find before us a forest resource so good and so desirable that more and more people want even increased opportunities to benefit from the legacy of the past?

So as the dust has begun to settle, and I could take the time to think more deliberately about this so-called new philosophy, I really have come to see it as an evolution .... a maturing of the way we think about forests, and of the values that they provide. I see in the ecosystem management movement a new spotlight on silviculture, and even yet another opportunity for us to provide important leadership to the forestry community.

THE NATURE OF OUR EVOLUTION

We all came into forestry at different times and bring to the present a wonderfully divergent array of experiences to share and draw upon. For me, entering forestry in the 1950's, it was an initial emphasis on timber, and rightly so. The nation had entered a post-war era of expansion and growth, with a mushrooming population that needed thousands of new units of affordable housing. Our industries and commerce demanded increased amounts of wood and wood-based products to sustain their growth. So a national policy emerged that emphasized timber on most private and public lands, and sought to insure a non-declining sustained yield of accessible commodities. We put a high value on creating stand- and forest-wide *uniformity, consistency,* and *homogeneity.* And we did it.

Yet even during the timber-dominant era we never forgot the other values. We knew about the needs to protect water supplies and prevent erosion. And we did. We recognized the values that people derived from wild plants and animals, and we incorporated measures to improve their habitats. But we did it as an adjunct to our timber management. In many cases it worked. We heard the demand for increasing the abundance of prime game animals and fishes, and saw the opportunity that timber cutting provided for improving conditions for those creatures. Also, we recognized that people would use our roads and trails to access the forest for recreational use, even though they primarily came for hunting and some camping. So we added parking areas and turn-abouts, and used construction standards that led to roads people could traverse in their automobiles. That worked, too, and helped to promote a dramatic increase in recreational use of forests.

Despite this broadening of effort, we really saw these opportunities as tangential to and a consequence of our timber management. In similar fashion, other resource professionals worked as diligently to set aside special areas for wildlife management, recreational use, watershed protection, and grazing. And they followed a parallel philosophy: to optimize whatever single purpose a landowner assigned to the land, but to also take cognizance of side effects that would have value to people.

Then came the 1960's. The continued period of prosperity and peace had brought higher wages and more leisure time to all of us. Automobiles and roads improved, and more and more of the countryside became readily accessible. Particular change occurred near the newly emerging interstate system that provided opportunities to travel long distances in a short time, and to escape the urban centers to find weekend refuge in the forest. People liked what they saw, and began visiting the forest more and more.

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Concurrently, people also took new interest in environmental quality, and increasingly connected the condition of the environment with the quality of their lives. They saw the forest as a place to realize quality opportunities for relaxation, and began interacting directly with our timber, wildlife, and water management. This brought us face to face with conflicting demands that we had to address and somehow resolve. And we began to do it.

Over time as more and more people moved to the urban areas and employment increased in industry and commerce, they became detached from agriculture and its concepts of production from the land. Gradually, new issues emerged, such as a lessened awareness forests as the source of paper and solid wood products for their homes and places of business. And many people lost sight of the need to both cut trees and grew them to insure a stead supply of the requisite solid wood and fiber products. At the same time, people demanded more of the non-commodity benefits that forests provide, and increasingly came to view tree cutting as a conflict with the values of primary concern. In response, we began looking for ways to mitigate the conflicts between timber cutting and recreation, and to deliberately manage lands to integrate a complex of *uses* in stands and across forests. We reasoned that by following a philosophy of multiple use, everyone could realize a fair share of a broad array of benefits, and that would prove satisfactory for the objectives.

In the process, we continued to focus on *uses*, and upon optimizing a package of complementary benefits that people could derive from the lands. This represented an evolution from the period when we tried to deliberately optimize a single kind of use, into a new era where we tried to optimize some predetermine package of benefits that included an appropriate mixture timber, wildlife, water, recreation, and anything else of concern to the people.

This change didn't happen over night. It evolved as we recognized the shift in public and landowner interest, and as we adapted our management and broadened our silviculture to accommodate the changing objectives for forestry. We still focused on *uses*, and we did not always find well-proven schemes for integrating the opportunities of interest, or even for understanding what people wanted. We had to figure out what they meant, and how that would translate into different kinds of stand conditions or use opportunities. It took creativity and imagination in the 1960's, and an adjustment in how we had "traditionally" done business.

This metamorphosis into the multiple use management didn't come easy for many of us. Really, we asked questions like:

But what have we done wrong?

Haven't we left the forest in good condition and highly productive?

Aren't the animals and flowers thriving, and doesn't abundant amounts of high quality water flow from the land?

Through hindsight, I see that we went through a time of transition when we struggled to find an appropriate direction for the future, and as we took stock of what we had accomplished in the past. The new philosophy of multiple use had come about through a long period of change and evolution, but to many it all seemed so sudden and so different, and somewhat confusing.

This concept of multiple use didn't require a drastically new silviculture. Rather, we evolved in our thinking and management over time, gradually shifting from a somewhat simplistic approach of concentrating on *one* resource at a time, to recognizing that as we managed for one value we could also manage for others simultaneously. In the process of wrestling with these ideas, we became increasingly skilled at identifying the kinds of forest and stand conditions that would have value in serving the divergent interests of people. And in the process we became adept at developing forest management plans and silvicultural prescriptions to bring those desired conditions to reality. We continued to gear our management to satisfy a set of well-defined objectives, but ones that had become more diverse and more multi-dimensional. Said another way, we matured from practicing silviculture *on an ecological basis*, to doing silviculture *by taking an ecological perspective*, to eventually seeing silviculture *as a process of ecosystem maintenance and renewal.* Yet through all this change, we still developed our silviculture based upon well-defined objectives that addressed well-recognized needs and opportunities.

PUBLIC INTEREST CHANGES AS WELL

Through later stages of the multiple-use era, people began to ask how we could keep our forests healthy and robust, and how we could sustain a broad array of benefits into the future. They asked about sets of values that we had not yet recognized as common to forestry, as well as the ones that we routinely derived from the land. And these questions increasingly dealt with non-marked values, even to the point of assigning them more prominence in some places than the people gave to commodity benefits. That added confusion, too. After all, how would our nation continued to thrive unless we provided the wood-based products that supported so many aspects of our business and private lives?

So toward the end of the multiple-use era as we saw a change in societal attitudes toward natural resources, we began to put less stress on *use* and more on asking *what kinds of conditions* would sustain the desired values into the future. Through the findings of science we also had assembled more evidence about the complexity of forested ecosystems, and the interdependent nature of components that make forests unique and valuable. And these emerging realizations led us to a new kind of philosophy ... one recognizing that the actions we take at one place might affect the nature of things across a broader expanse of the countryside as well. We have also come to better appreciate that when planning the silviculture for one stand, we must think about how that meshes with aspirations for the forest as a whole. And we have learned that when planning the management for a single forest, we must also look at the possible effect on conditions

within the surrounding landscape. All together, this has meant moving one step beyond the traditional boundaries for planning, and learning to better recognize how our activities would fit into the bigger scheme of things that surround us, both in the present and for the future.

SO WHAT HAPPENED TO THE TIMBER?

When all of this began to surface, I had an opportunity for conversations with two people who helped greatly to forward my thinking. First, Winifred Kessler suggested that we could now concentrate on creating desirable ecologic condition across the landscape .... ones that kept the ecosystems robust, dynamic, and diverse. She also argued that human uses or benefits would flow from these desirable conditions. So we would concentrate on managing forests to create and maintain some desired combination of vegetal attributes in stands and across landscapes, knowing that many benefits would accrue from having those conditions in place.

I still don't fully understand exactly how to measure success with this evolved venture, or even what indices to use in making assessments of the outcomes. But that will come. For the interim I can think about factors like ecosystem resiliency, continuity, complexity, interdependence, and renewability. Perhaps we might take stock of their condition by assessing attributes like:

1. the health and continued productivity of vegetation and faunal communities over the long run;

2. soil stability and nutrition;

3. consistency in soil and land form conditions that might affect water cycling, regime, yield, and quality;

4. sustained availability of suitable habitats for indigenous plants and animals, or acceptably altered communities of them; and

5. continuance of acceptable visual qualities for the intended non-commodity purposes.

Allen and Hoekstra (1995) articulated a set of indices in somewhat different terms, using:

1. *Response indicators*—changes in the status and condition of organisms, communities, and systems

2. *Exposure indicators*—measures of exposure to stress factors

3. *Habitat indicators*—changes in or abundance of conditions that support living organisms

4. *Stress indicators*—development of hazards or a tendency toward actions that stress an ecosystem

Whatever we settle on, we would reject those actions that will not likely have a neutral or positive effect.

The other help came from a conversation with Hal Salwasser. He argued that we could only realize the desired results if we practiced silviculture, and probably more intensively than we had in the past. Especially where features of the vegetation community determine the desired conditions, we would often need to manipulate the density and structure of stands, as well as the species composition. And that means silviculture. So I have come to recognize that we must do it *one stand at a time*. Oh, we don't forget the forest- and landscape-wide needs and opportunities. In fact, we begin by defining what we need across larger areas, and how to intermix different stand conditions to realize a desirable result. But we need to create the desired conditions stand, by stand, by stand .... until we have finally realized an appropriate balance at a broader spatial scale.

This new philosophy doesn't ignore the timber, the game animals, the hiking trails, or the way things look. Rather, it says that we finally can approach these opportunities in different ways. We no longer need to maximize the package of uses a forest can provide. It really says that we have moved away from seeking *simplistic* solutions for optimizing the special interests of a particular group of clients. It says that we stand in a era of more complex silviculture that addresses more long-term opportunities. And what a wonderful challenge that affords.

So at least during my career we have evolved from functioning as silviculturists serving management objectives focused on *timber*, to silviculturists serving management objectives focused on *multiple uses*, to silviculturists serving management objectives focused on *creating and maintaining desirable vegetation conditions*. And where we once integrated uses, we now integrate conditions across time and space to insure the continuance of robust and dynamic forests that will have value to people. In the process we will continue to cut timber, because that frequently proves the most cost-effective way to either tend or regenerate existing age classes (the primary functions of silviculture). But we do it not for the sake of timber. Instead we do it because timber cutting helps us to create and maintain the conditions deemed important to the present and the future. Said succinctly, we now will concentrate on ecosystem maintenance and renewal, with due concern for the effects over both the short term, and for an ecologic time scale as well.

BUT DOES THE PRESENT ALSO REPRESENT A REVERSAL TO THE PAST?

I find all of this exciting, and challenging. It gives me new opportunities for adapting to changing sets of objectives and purposes. It challenges me to anticipate how altering the structure and condition of a stand for one purpose might affect its condition for another value. It encourages me to intensify my dialogue with wildlife biologists, plant ecologists, hydrologists, recreation managers, visual quality experts, and a wide array of other resource specialists. It forces me to seek out and adopt compromises in some cases, and opens new opportunities in others.

Despite this exciting opportunity, I begin to see a bothersome trend emerging, and wonder if it reflects some kind of backlash response. For even while silviculturists and other foresters work hard at all the things that ecosystem management represents, I see an increasing tendency within some publics to suggest that we should begin narrowing the range of objectives that guide our planning and management, and begin setting aside more and more lands for special uses .... special *dominant* uses. I hear suggestions that we cannot maximize the benefits deemed important to some special interest groups if we continue to create and maintain conditions that ultimately integrate opportunities for a mixture of recreation, commodity, wildlife, hydrologic, and visual values. I see this in the tendency to demand that public foresters set aside areas to support special recreation uses, to enhance a specific group of wildlife, or to exclude commodity production activities that some publics consider incompatible with their own interests.

So I wonder if we have begun to see on the horizon an even new era that would move us back in time, a movement that would discard valuable lessons from the multiple-use era, and a movement that would put us squarely back to arguing about what should go where, and how to limit the options in order to maximize one particular set of objectives. This seems a contradiction to the evolution that brought us to ecosystem management. It makes me wonder what lies ahead ... more maturing, or a retrogression instead.

THE SILVICULTURAL CHALLENGE

Therein I see a challenge for silviculturists. We have an opportunity to show the options for creating and maintaining desirable conditions that will prove ecologically sustainable and also institutionally, socially, and financially valuable. We can *adapt* to the opportunities that time and maturing brought to silviculture, and demonstrate how integrative approaches set up the conditions that insure long-term ecologic stability across landscapes. We can lead the way into the future by the way that we deal with the present.

In my judgment, it will not require a new silviculture, *per se*. We already have a wide array of techniques in our tool kits. Further, time has shown us what to expect from applying them in different combinations, by different sequences, at alternative times, and with varying intensities. Both research and experience indicate much about the probable outcomes, and that allows us to show people how a variety of silvicultural systems and silvicultural techniques help to create and maintain alternate sets of desired ecosystem conditions at both the stand and forest levels. We just need to keep improving our capacity to articulate these potentials, to plan creatively how to use the techniques already available to us, and to do a better job in helping others to understand the alternatives that silviculture offers. We need to put our creativity into action, and put silviculture to work to show concrete examples of what appropriate management offers.

This will not come easily ... it has not in the past, and probably will not in the future either. But we need to do it. And we need to keep our minds open and ever expanding to encompass the new opportunities that time has brought to us. We need to stir up the courage to take the risk of continuing to explore alternative values that silviculture can provide, and what that means about trying new ways of doing business.

As we make the move, we push ourselves into the future. Then I suspect we will eventually look back on these times of ecosystem management as still another stage along the evolutionary pathway toward something yet to come .... something that matures from the past and the present, and that opens additional opportunities we can still not comprehend.

So it is *change* that challenges silviculture today. And it is continued *change* that will challenge silviculture in the future. But thanks to a collection of willing and imaginative people who take the challenge and do the deed, we will succeed. We will evolve into whatever the future brings. We have no other choice.

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Stewart's Maxims: Eight "Do's" for Successfully Communicating Silviculture to Policymakers

R. E. Stewart[1]

Abstract.—Technical specialists may experience difficulties in presenting information to non-technical policymakers and having that information used. Eight maxims are discussed that should help the silviculturist successfully provide technical information to non-technical audiences so that it will be considered in the formulation of policy.

INTRODUCTION

> "Some of the biggest problems in silviculture are getting owners and society to define their management objectives and, especially, the degree of priority attached to various uses. Foresters can determine how much of what uses are feasible, but the owners determine actual policies about allocations. It is the responsibility of foresters to work out the details, which include the design and conduct of silvicultural treatments. Management is hamstrung if owners, particularly legislative bodies, fail to provide for the making of hard choices about allocations of forest uses and leave them to be fought over by single-minded user groups. Even worse problems can be caused by amateur prescriptions of silvicultural practices through simplistic rules ordained by legislatures, courts, or accountants." (Smith, et.al. 1997.)

This quote from the latest edition of "Practice of Silviculture" captures a critical issue in today's controversy over forest management. However, it provides no solution to this dilemma. How can the the silviculturist bring technical and biological information to the table when public - or private-land management policies are being discussed? Those who have been involved in providing such information to the policymaker often have tales of frustration. They have given their best only to walk away feeling that the information they contributed was ultimately ignored while a "political" decision was made.

The fundamental problem can often be traced to one or more of the following: miscommunication resulting from use of technical jargon or a clash in values; misunderstood or conflicting agendas and needs; or misunderstood roles. This can, and does, result in non-use or misuse of technical information and, ultimately, biologically unsound policy decisions. The ultimate goals for the silviculturist are to assure that the biological options and constraints of a policy decision are both understood and considered by the policymaker when establishing natural resource policy.

I am a silviculturist by training. My early career was in the forests of the Pacific Northwest in Oregon and Washington. I worked in practical forestry as a field forester for the State of Washington, and later as a scientist with the USDA Forest Service Pacific Northwest Forest and Range Experiment Station. Later, I became a policymaker as Station Director for the Pacific Southwest Forest and Range Experiment Station, as Regional Forester for the Pacific Southwest Region, and now as Acting Deputy Chief for Programs and Legislation. I have experienced the frustration of miscommunication and misunderstanding of technical information from both sides. Therefore, I am both comfortable and, I believe, qualified to speak on the topic of effectively communicating silviculture to policymakers.

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STEWART'S MAXIMS

I approach this topic through the use of eight "Stewart's Maxims" or "Eight 'do's' for successfully communicating silviculture to policymakers." These maxims are based on successes and failures from my own experience. They are: (1) Know your audience; (2) Understand the policymaker's needs: (3) Know your role; (4) Focus on your message; (5) Avoid jargon and value-laden terminology; (6) Be professional; (7) Ask questions to assure that you are understood; and (8) Create options. I will briefly discuss each of these.

1-Know Your Audience

As with any presentation to any individual or group, you should begin by knowing your audience. There are some key questions that you should answer before you prepare your presentation. Who will be making the decision? In a room full of people, only one may have the authority to make the actual decision. Or, it may be made collectively by the group through concensus. In any case, its important to know something about the decisionmakers. What is their background? What do they know about the subject? What related decisions have they made in the past? How do they like to receive information?

Some policymakers have a technical background in your subject area. If so, they may understand, and even appreciate, the technical details. Others have absolutely no knowledge or interest in the details. Some policymakers are visually oriented while others are more auditory. Some like details, while others just like to get to the bottomline.

Its up to you to find out the policymaker's background, including their style in getting and using information. Then, you should use this knowledge responsibly to make your presentation most helpful.

2-Understand the Policymaker's Needs

Its important to go beyond a simple understanding of the policymaker's background and how they have dealt with similar issues in the past. To improve your effectiveness and usefulness to the policymaker, I suggest that you try to understand their needs. For example, what pressures and

constraints are they under? Who are the key outside players influencing the decision? An example here may be helpful.

A number of years ago, I was scheduled to testify at a field hearing on a very controversial subject. In preparation for the hearing, the national forest had arranged a field tour for the two local members of Congress. As we traveled around the forest together, it became apparent that, while the two Congressmen were sympathetic to the needs of the Forest Service, their constituency, several local environmental groups, were pushing them toward a restrictive legislative fix. They were obviously uncomfortable with this, but had no ready alternative. Now, I'm one of those who believes that legislative fixes for basically biological issues do not often make either good biology or good policy. However, if we didn't find a solution for them, they would be forced into finding one for us. The two Congressmen needed a solution that would get them "off-the-hook."

During the evening after the field trip, we met with the Forest Supervisor and the key forest staff. We brainstormed some solutions that we could live with, and following several phone calls to get acceptance by other Forest Service and Administration players, we developed a workable alternative. Some final work the next morning allowed us to make a preemptive policy statement at the hearing later that day. The statement caught the environmental community off-guard, resulted in very favorable press coverage for the Forest Service, and produced a grateful sigh of relief from the two Congressmen. The result was a workable policy, improved credibility for the agency, and two appreciative members of Congress.

3-Know Your Role

"Through science, we can describe options for addressing management problems and provide assessments of their consequences. But science simply will not and can not give society 'the answer.' Science is only a tool—in the end, all managerial decisions are moral, not technical" (Thomas 1994).

You are not the decisionmaker; your role is to present the factual information and, when fully disclosed as such, your professional opinion. Your goal is, to the best of your ability, to assure that the needs of the forest are appropriately considered and to help find creative, biologically-sound solutions. I'm reminded here of statements made by the first Chief of the Forest Service, Gifford Pinchot. These are from his list of eleven maxims for guiding the behavior of foresters in public office taught to his students at the Yale School of Forestry from 1910 to 1920. The first maxim says, "A public official is there to serve the public and not to run them." The seventh maxim says, "Don't try any sly or foxy politics, because a forester is not a politician."

In some respects, the silviculturist should approach the task of informing the policymaker as a teacher and coach. In the past, I felt that it was my job to convince and cajole the policymaker into making the "right" decision. I often walked away frustrated that the person had made another one of those "political" decisions and ignored the biological facts. I have since learned that the best biological solutions that aren't politically implementable are not solutions at all.

4-Focus On Your Message

The **KISS** principle (**K**eep **I**t **S**imple **S**tupid) is generally the best approach to get your point across. Remember my first and second maxims: Know your audience and their needs. What specific points do you want to make? What is the most effective and easy way to make them? Think through your message carefully. Don't overload the listener with interesting but unnecessary information. Know what you want to say, what the key messages are, and then stick to them. It is best to aim for only a few key points, carefully and thoughtfully made, but reinforced often. Rarely will anyone remember more than three or five key points, so don't waste your brilliant thoughts all at one time. Save some for later.

Most policymakers are very busy with many, often complex issues. They may have only limited time to become engaged in your issue. While it may be of intense interest to you, it may be only one on a long list of politically hot topics needing the policymaker's time. This presents a challenge to, first get his or her attention, and then to efficiently and effectively present your information. It's a good practice to try to say what you have to say in ten minutes or less and to use a handout summary of your information on two pages or less.

Finally, those of us from technical or scientific backgrounds tend to throw better and better technical or science-based solutions at what are fundamentally social- or value- based problems. We then wonder why our solutions don't work or are rejected.

Because many people are visually-oriented, a simple picture, graph, or diagram can quite literally be worth a thousand words. Unfortunately, finding ways to simply illustrate complex ideas is difficult and requires a real talent. It may be worth the effort to test your presentation out on someone who is not well acquainted with your subject before you deliver it before the policymaker. This should provide some indication of the clarity of your information. You should also test any visual aids at the same time. This extra step may be well worth the effort.

5-Avoid Jargon and Value-Laden Terminology

Speak and write simply and plainly. Avoid technical jargon and acronyms or complex, esoteric biological arguments. Failure to do so confuses the non-technical policymaker, assures that your points will be ignored, and makes you appear to be intellectually arrogant. Again, I refer you to my first maxim, know your audience. If you don't communicate in language your audience understands, **you really don't communicate**. A bit of Gifford Pinchot's wisdom is appropriate here. His sixth maxim says: "Get rid of the attitude of personal arrogance or pride of attainment or superior knowledge." A good attitude is humility, remember you don't know everything.

Remember the quote from former Forest Service Chief Thomas that all managerial decisions are, in the final analysis, moral not technical (Thomas 1994). It is important that we try to keep our own values and biases out of our efforts when describing options for addressing problems or providing assessments of their consequences.

Because the practice of forestry arises out of a basic utilitarian view of the forest, its language often assumes a particular value system. We must be careful, if we are to be heard, to avoid such value-laden terminology.

I remember being on a field trip with a Forest Service District Silviculturist and several people from the local environmental community, including the president of the California Native Plant Society. As we walked through a magnificent old-growth forest, the silviculturist described the stand as old, decadent, and on the decline. In other words, from a forester's viewpoint, ready for harvest and conversion to a thrifty young forest. While she described this stand she was unwittingly conveying a value system. That this was so was verified as I watched the body language on the president of the California Native Plant Society. With an angry red face, he declared that it was not "a decadent old forest" but a "beautiful ancient and primeval forest. This was an obvious, and clearly avoidable, conflict in values. From this point on, the two ignored each other and no further useful communication occurred for the remainder of the field trip.

6-Be Professional

When you make your presentation, dress and act professionally. Do not compromise your professionalism regardless of the importance of the decision. If you expect to be asked for your advice again, you must have a reputation for consistent, unbiased, professional information and opinion. This means full disclosure, even of the information that does not support your personal position.

Here again, I fall back on the good advice from Gifford Pinchot's eleven maxims. The eighth maxim says, "Learn tact simply by being absolutely honest and sincere, and by learning to recognize the point of view of the other man and meet him with arguments he will understand." The ninth maxim says, " Don't be afraid to give credit to someone else when it belongs to you; not to do so is the sure mask of a weak man. But to do so is the hardest lesson to learn. Encourage others to do things; you may accomplish many things through others that you can't get done on your single initiative." Maxim ten says, "Don't be a knocker; use persuasion rather than force, when possible. Plenty of knockers are to be found; your job is to promote unity." And finally, maxim eleven says, "Don't make enemies unnecessarily and for trivial reasons. If you are any good, you will make plenty of them on matters of straight honesty and public policy, and you need all the support you can get."

Be honest and sincere. Share the credit. Build up, don't tear down. Don't go looking for trouble. It is not difficult to understand that following these four rules will increase your credibility and your usefulness to policymakers.

Again, a humble attitude is essential. We do not have all the answers. Advice from a 1930 editorial in the Journal of Forestry is still useful today:

> "The world is, and doubtless always will be, in a state of change. Old requirements must be modified, new ones met, conflicting ones harmonized. What is right today may be wrong tomorrow. Keeping a policy up to date is therefore fully as important as formulating it in the first instance.
>
> Conceivably some Moses among us might be able to outline a forest policy perfectly suited to present conditions. That it would be unanimously approved even within our own Society [Society of American Foresters] is, however, unlikely; and that it would be adopted by the country at large is inconceivable. Things do not simply happen that way in a democracy where every man is entitled to his views and his vote.
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> That foresters less frequently see eye to eye today when they are engaged in a hundred diverse activities than twenty years ago when they were practically all in government employ, is as natural, and perhaps as desirable, as it is inevitable. On the whole this is cause for congratulation, since the truth is mostly likely to emerge from differences of opinion fully, frankly, and good-naturedly discussed. It means, however, that ample patience, tolerance, and tact must be used in reaching decisions in which a majority of the profession can concur, and that agreement on most points may be impossible when the facts are not fully known or when they point in more than one direction (Society of American Foresters 1930)."

7-Ask Questions

Don't be afraid to ask questions during your presentation to determine if you are being understood. Its counterproductive to go completely through your presentation only to find that your audience didn't "get it." The policymaker may be embarassed to admit he or she doesn't know what you are talking about, so its up to you to make it easy for them to admit ignorance. Watch body language—like a blank look—for signs that your audience has either tuned out or is lost in one of your elegant technical points.

8-Create Options

Our problem as professional foresters is that we may be unwilling to propose or accept any solution that does not appear to be perfect from a biological or professional viewpoint. But, as I have suggested, we suffer from less than perfect and complete knowledge, we may be bound by our own biases, and even the best biological solution that can't be implemented in the prevailing political climate is no solution at all.

I'm not suggesting that we should compromise our professional integrity. Ultimately, our personal integrity and truthfulness is all we have. What I am saying is that we need to understand our own limitations. There almost always are

more than one workable solution to a problem. Be prepared to create options for the policymaker. A good question to ask is, "What would a successful outcome look like?" Allowing the policymaker to answer this question will help clarify the probable decision space that the policymaker feels that he or she is working within. Your job then, is to increase either the decision space or provide new options within the existing decision space, all within the biological limits of the ecosystem. As you do this, make the full range of options and their consequences clear in a professional manner. And, remember my third maxim: Know your role! You are not the decisionmaker. Once you have given your best effort, leave the decision where it belongs.

I believe that if you practice these eight maxims, you will be in demand and at the table when critical policies involving the nation's natural resources are being made. The next time you are preparing for a presentation before someone who will be using your information to make a decision, try them out.

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Is The Northern Spotted Owl Worth More Than The Orangutan?

Donna Dekker-Robertson[1]

Abstract.—When policymakers choose to reduce the amount of wood harvested on National Forest lands, the demand for wood products must be met by reducing consumption, increasing recycling, substituting nonrenewable resources, or importing more wood. Reducing the amount consumed and increasing the amount recycled will not significantly impact global demand, and both substitution of nonrenewable resources and increased importation of wood products have negative consequences. Establishing high-yield plantations of genetically improved trees grown using intensive silviculture on federal lands may allow the United States to set aside other valuable areas without exporting environmental degradation or increasing carbon dioxide emissions.

I used the word "worth" in the title deliberately. To me it seems that we spend a lot of time thinking about what we want: clean air, clean water, biodiversity, nice houses, recreational opportunities, low taxes...But we aren't often asked "What's it worth to you? How much would you spend to have these things? Or what would you be willing to give up to have them?"

Is it worth more effort in recycling? Many of us agree and the amount of paper and other materials recycled is going up rapidly.

Is it worth keeping things longer and repairing them rather than replacing them? Hmm...

Would you give up having a new house when the one you have now is getting old or too small?

Would you give up your new deck, your new kitchen, your disposable diapers, your foods packaged in convenient cardboard boxes, those photos of the kids from the last vacation?

Is it worth curbing our consumption?

Or is it worth extinctions in places you may never visit nor even know much about?

A few years ago our Congress passed the Endangered Species Act when many people agreed that we wanted to save species from extinction, particularly extinction caused by our actions. Today hard questions are being asked about its unintended (and unforeseen) consequences. Our Senators and Representatives usually cast that debate in terms of job losses and infringements on the rights of private property owners. However, another unintended consequence of the Endangered Species Act and other legislation that changes the management objective of National Forest lands is to force us to look elsewhere to satisfy our demand for wood products.

I think that we resource professionals have read and thought about the impact of forest harvesting. I think that the American public has, too. We've heard from many of them loud and clear: they don't like it. They don't like clearcutting, they don't like road construction, they don't like loss of habitat. They don't even like it when we suggest thinning operations that will keep the forests in the West from going up in smoke every August. But we know from what they buy that they do like wood-framed single-family homes, toilet paper, wooden furniture, decks, cardboard boxes, fireplace fires, photographic film and Scotch tape...I believe that many American voters have lost the fundamental connectivity between everyday products and the raw materials used to make them, just like the urban kids who think that milk comes from boxes at the store.

Expand on that a moment. Where does that box come from? It's a paper product. Its parent material is wood. In the Pacific Northwest the odds are that it was made from residues generated at a sawmill, a sawmill that was cutting logs into lumber. Where did the sawmill get the logs? They were cut from a forest somewhere. Historically, those forests were also in the Pacific Northwest. But with the injunctions, the lawsuits, the appeals, and above all the uncertainty associated with this, sawmill owners are looking further afield, from Tierra del Fuego to Siberia (Sleeth 1994a,b).

According to wood scientist Jim Bowyer (1992), when we remove lands from timber harvest, we have three options. We can reduce our demand and recycle. We can substitute other materials for wood. Or we can import our wood from other countries.

OPTION ONE: REDUCE DEMAND AND RECYCLE

Worldwide reduction in the consumption of raw materials, including wood products, seems unlikely in view of global population trends. According to the U.N. (1996), the world's population is growing at 1.5 percent annually. As Jacques Cousteau (1992) noted in his address to the world's leaders at the summit in Rio, "Every 6 months, the equivalent of France (50 million) is added. Every 10 years, there is a new China born in the poorest regions of our Earth."

Global per capita consumption of wood has increased from 0.6 to 0.7 cubic meters per person per year from 1950 to 1989, an increase of 12 percent (FAO 1961; FAO 1991). Interestingly, even today more wood is harvested globally for fuel and subsistence use than industrial use, by about 53 to 47 percent. The amount used for fuelwood is projected to rise worldwide about 24 percent by 2010 (FAO 1993).

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Pulp and paper consumption has also increased substantially. Paper and paperboard production has increased threefold worldwide since 1960, and the FAO projects that by 2010 pulp and paperboard production will be five times what it was in 1960 (FAO 1994). The increased production will go predominantly to developing nations as their economies and populations grow (Barbier and others 1994).

The amount of wood used industrially worldwide will also rise between 15 and 40 percent. Overall, the world roundwood consumption (that is, wood harvested both for fuel and for wood products) is projected to increase about 32 percent by 2010 (FAO 1993), or one-third again what is presently consumed.

The suggestion is often made that we should just let the market take care of the problem, that as wood prices rise demand will fall. When people using a product are well-off, they will normally pay more or substitute another product when prices rise. When the people using the product are living submarginally, however, there may be no substitutes; the effect of diminished supply and rising prices is to force a drop in their standard of living. One unpleasant side effect of a decreased standard of living is that it promotes higher birthrates. Today Haiti is well on its way towards total deforestation; two-thirds of the island's forests are gone, and the remaining third is quickly being used for charcoal (Cousteau 1992). No substitute product is available, and the standard of living is among the lowest in the western hemisphere. The birthrate, however, is one of the highest. Is that the destiny we should bequeath to the world's children?

Here in the USA, per capita consumption of wood fiber is increasing, not decreasing as some have suggested. Since 1970, it has increased 30 percent to about 2.4 cubic meters per person per year; that is nearly 3.5 times the global average (Fig. 1) Total wood consumption in the United States has increased 50 percent since 1970, from 12.5 to 18.7 billion cubic feet per year (Haynes and others 1993).

Every year, every American consumes a tree 100 feet tall and 19 inches in diameter (derived from Haynes and others 1993). A forest of such trees, roughly 250 million of them, might cover some 3 million acres, or just under 5,000 square miles. That is an area roughly the size of Connecticut (4,872 sq. miles). In 1993, Americans consumed 20 billion cubic feet of wood and wood products. That may be visualized as a train of some two million fully loaded boxcars encircling Earth at the equator. Each year, enough trees must be harvested somewhere to load that train with the wood required to satisfy our national appetite (Daniels 1993).

Recycling is an important and growing source of fiber, slowing the rate at which virgin fiber is needed. Wastepaper utilization rates increased from 25 percent in 1986 to 30 percent in 1992 (Haynes and others 1993), and still continue to improve. However, because recycling degrades quality, there are limits to the number of times that paper can be recycled. For some uses it may be as many as 4 to 9 times through the process, but in any case some 15-20 percent of fibers are lost in each cycle. For that reason virgin fiber must be constantly added.

Solid-wood recovery programs are still uncommon although they may play a larger role in the future. Projects exist or are being researched that chip used pallets for particleboard, add them to municipal sewage sludge, or use them as feedstock for hardboard plants (Davis and Jansen 1992). Old wood may become more common in composite products used for road construction, sound barriers, posts, or solid cores for doors. Recycling either paper or solid wood has the added benefit of reducing landfills (Ince and others 1995).

Unfortunately, growth in demand for wood products worldwide cannot be met solely by recycling. Since populations continue to increase, the demand for fiber will simply outstrip the supply no matter how good the utilization rate becomes.

If global populations are rising at 1.5 percent annually, and each new person added uses 0.7 cubic meters of wood each year, then over the next 20 years we will need an additional 2.7 billion cubic feet **per year** to keep up with global demand. That's another British Columbia or 6 more New Zealands every year. And it is senseless to pretend that population growth won't produce 11 or 12 billion people on Earth in the next century; we need to plan now and plant now to meet their demands for natural resources.

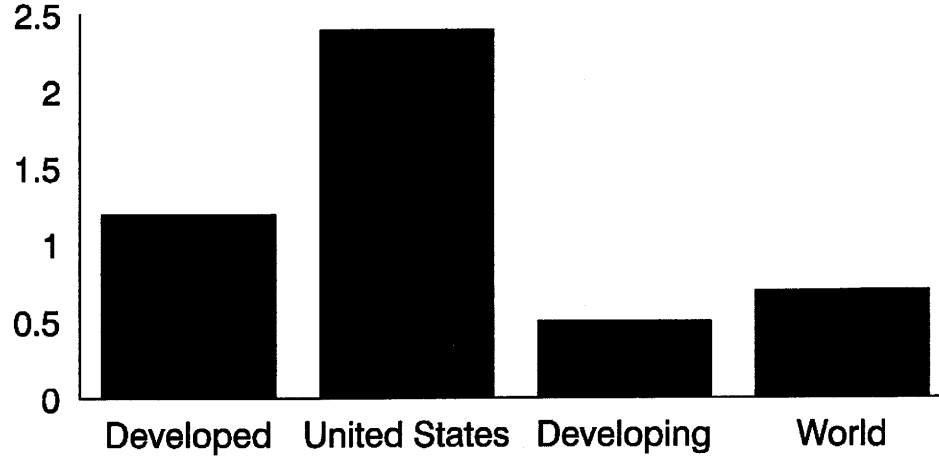

Figure 1.—Global per capita consumption of wood, in cubic meters. Each American uses 2.4 cubic meters of wood annually, which is twice the average of the developed nations and nearly 3.5 times the global average (FAO 1993).

OPTION TWO: SUBSTITUTE OTHER MATERIALS FOR WOOD

A second way that we could cope with declining wood supplies from National Forest lands would be to substitute other materials for wood. Other agricultural products may be used in lieu of wood fiber to make paper. Competing materials also exist for construction purposes, such as steel or aluminum studs, concrete slabs rather than floor joists, and vinyl siding. However, such substitutes may be less environmentally friendly than wood in a number of ways.

Paper is a versatile product that has been made from rags, flax, hemp, bagasse, kenaf, and a number of other materials. The desired end use determines the best composition of fibers, and wood fiber is well suited to a number of these uses. Nevertheless, it has been suggested that it would be more environmentally favorable to switch to crops such as bagasse and kenaf to make paper. Bagasse is a by-product of sugar cane cultivation and such by-products can and should be used where possible. But a plantation of sugar cane, or kenaf, or any annual crop is not as biodiverse as a plantation of trees which stays in place for many years (Libby 1994a). Furthermore, annual crops are generally grown with the assistance of chemicals, unlike plantations of forest trees on National Forest lands where chemical use is highly restricted. Should policymakers choose to press for more agricultural fiber in papermaking, they must consider that environmental costs will be shifted to agricultural lands rather than being eliminated.

One of the long-term goals of National Forest management is sustainability of the forest through time. Forests do grow back following all but the most damaging of disturbances, and it is undeniable that wood is the only building material (with very minor exceptions) that is renewable. Steel, aluminum, concrete and plastic are not, so deposits of the parent materials of these products must be continuously developed. The sites from which these materials are extracted must eventually be reclaimed. Lippke (1992) noted that, "logic and maybe even intuition would suggest that using renewable resources rather than nonrenewable resources would better protect the environment."

While substitutes for wood may in some cases be cheaper, the price does not always include another cost: energy requirements. In the 1970s a panel that reported to the National Science Foundation analyzed the amount of energy necessary to extract, transport, and convert various raw materials into finished products (CORRIM 1976). Since much of the world's power is generated by burning fossil fuels, they used the unit "a million Btu (oil equivalent)" as a uniform measure of expressing energy consumed. So, for instance, the production of a ton of softwood lumber is said to require 2.91 million Btu, or half a barrel of oil. The production of a ton of steel studs requires 50.32 million Btu, or about 8.5 barrels of oil.

Substituting other materials for wood products therefore comes at a high cost in terms of energy. The CORRIM panel compared the energy required to construct 100 square feet of either exterior wall, interior wall, or floor. They found that steel framing for an exterior wall requires 13 times more energy than wood framing, while aluminum framing for the same wall is nearly 20 times as energy intensive as wood framing. A floor built with steel joists requires 50 times as much energy as one built with wood joists. Interior walls framed with steel or aluminum studs use eight or twelve times, respectively, the energy of wood studs to perform the same function (Fig. 2). Brick siding uses 25 times more energy than wood-based siding materials (as well as requiring much more labor to install). Even details such as wall-to-wall carpeting with a pad rather than hardwood flooring add up; the carpet/pad combination uses four times as much energy as wood.

Straight across, ton-for-ton comparisons are even more significant. From raw material extraction to finished product, the energy input is 70 times greater for a ton of aluminum than for a ton of lumber; 17 times greater for steel; 3.1 times greater for brick; and 3 times greater for concrete blocks (CORRIM 1976).

Here in the United States we consume approximately 18.7 billion cubic feet of wood every year, and most of what we consume is used industrially (Haynes and others 1993). About half of the wood consumed is used for lumber and veneer, and about 60 percent of that is used for construction. To substitute other materials for wood in construction on a large scale would therefore involve a significant increase in energy consumption, at least some of which would be generated by burning fossil fuels.

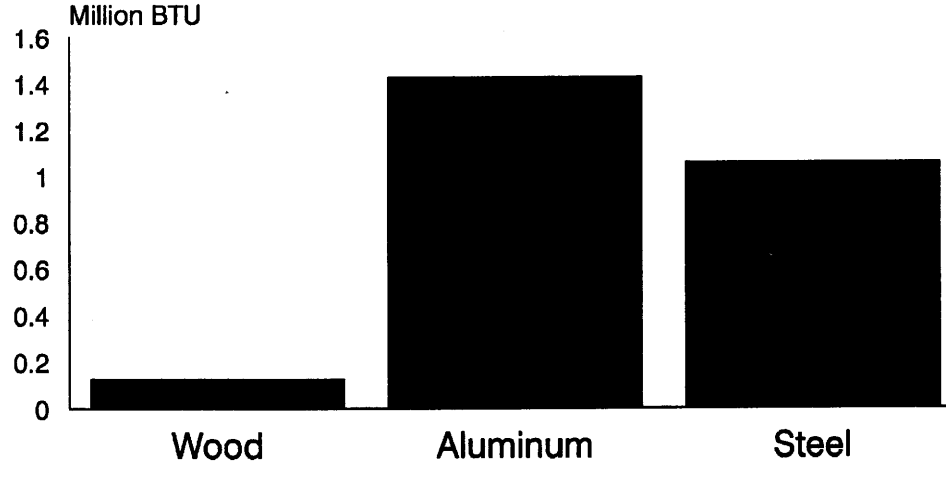

Figure 2.—Net energy consumed to extract, transport, manufacture and erect 100 square feet of interior wall using various framing materials (CORRIM 1976).

Each gallon of fuel oil burned adds 22.4 pounds of carbon dioxide to the atmosphere. Carbon dioxide is considered to be the most significant of the greenhouse gases that may contribute to global warming (Wigley and Raper 1992). Four of the most important global circulation models predict mean annual temperature increases of between 1.5 and 4.5 degrees Celsius as a result of carbon dioxide concentrations doubling. Scientists predict that could cause great ecosystem disturbances and losses, as the climate change would occur too quickly for the flora and fauna to either migrate or adapt (Monserud and others 1993).

Wood scientist Peter Koch (1992) estimated that for each 1 billion board feet of wood wholly replaced with manufactured substitutes, annual energy consumption increases by about 17 million barrels of oil, and carbon emissions increase by 7.5 million tons. In his worst-case scenario of an 8.25 billion board foot wood supply reduction from lands set aside in the Pacific Northwest, 141 million additional barrels of oil would be consumed to deliver the same products. That amounts to the cargoes of 117 supertankers the size of the Exxon Valdez, enough oil to fuel 11 million automobiles for a year. And, as a by-product of combustion, 62 million additional tons of carbon dioxide would be added to the atmosphere every year.

With marvelous serendipity, wood use has almost the opposite effect. Growing trees absorb carbon dioxide, sequestering the carbon and emitting the oxygen. The carbon remains stored in the wood for the life of the tree and beyond, after it is converted into products and used in the manufacture of structures. A number of preliminary analyses have even indicated that forest establishment and management as well as agroforestry could contribute to global carbon sequestration and reduce concentrations of atmospheric carbon dioxide (Schroeder and others 1993).

To sum up, Clive Whittenbury noted in the new book *Creating a Forestry for the 21st Century* (1997) that, "Wood has many well-described attributes, not the least being its manufacturing efficiency using solar energy. It is one of two large-scale converters of solar energy that meet the vast material needs of society; the other is agriculture. The vast collector areas of the forest inexpensively turn water and free carbon dioxide into vast quantities of biomass via solar energy. This is why wood is so important environmentally. Substitutes for wood used in construction start at a competitive disadvantage if they are evaluated using environmental criteria."

OPTION THREE: IMPORT MORE WOOD

So we've decided that demand isn't likely to fall and that substitution of other products for wood may not be environmentally friendly either. Our third option, then, is to import the wood we need from other countries.

What happens when we simply get our wood from somewhere else to replace wood from areas we've set aside in the United States? We begin to find out how connected the world really is. Ecologists from John Muir to the present have made statements that "everything is connected to everything." That couldn't be more true when discussing global trade issues.

In the global market, the United States is the world's largest importer of wood products (FAO 1993). The U.S. is also one of the largest exporters, second only to Canada (Brooks 1993). Oddly enough, we export some of the same products we import, notably softwood lumber. On balance, though, the U.S. is a net importer of wood products; nearly 20 percent of what is consumed domestically is imported (Haynes and others 1993). The vast majority of the wood imported is softwood lumber, almost exclusively from Canada (FAS 1996).

The largest markets for American wood products are Japan, Canada, Germany, South Korea, and Mexico. The value and volume of trade with Japan is more than twice the value and volume of trade with Canada, our second-largest export market. The largest single component of that trade is softwood logs, followed by softwood lumber (FAS 1996).

Softwood log exports from the United States as a whole peaked in 1988 and have been declining an average of 6.4 percent every year since then. In 1995 only 11.5 million cubic meters were exported, for an overall decline of 44 percent from the 1988 volume (20.8 million). Exports from the western region and Alaska have fallen at a rate of 8.2 percent annually and are only 51 percent of their 1989 peak (WWPA 1995). The vast majority of those logs go to the Pacific Rim, notably Japan (FAS 1996).

Softwood lumber exports show a similar pattern (Fig. 3). On average, the volume of softwood lumber exported from the United States has declined 7 percent every year since its peak in 1989, for an overall decline of 42 percent. Lumber exports from the western region and Alaska have declined by 8.9 percent annually since 1989 and have lost 53 percent of their peak volume (WWPA 1995). Again, the majority of the softwood lumber exported goes to Japan, although large amounts are also exported to Canada and Mexico (FAS 1996).

This presents some issues for policymakers to consider. It is probably a safe assumption that the steep decline in softwood exports has influenced the balance of trade between the U.S. and our trading partners in the Pacific Rim area, particularly Japan.

At the same time, the United States is increasing the volume of softwood log and lumber imports (FAS 1996). These markets are substantially influenced by housing starts in the United States, which bottomed out in the recession of 1991 before climbing again in the mid-90s (housing starts also dropped between 1994 and 1995) (WWPA 1995). In 1989 just after log exports peaked, about 95 thousand cubic meters of softwood logs were imported. In 1993, a year with a similar number of housing starts, 388 thousand cubic meters of softwood logs were imported, an increase of 410 percent. In 1988, in the run-up before the volume of softwood lumber exported peaked in 1989, the United States imported 33.5 million cubic meters of softwood lumber. In 1995, a year

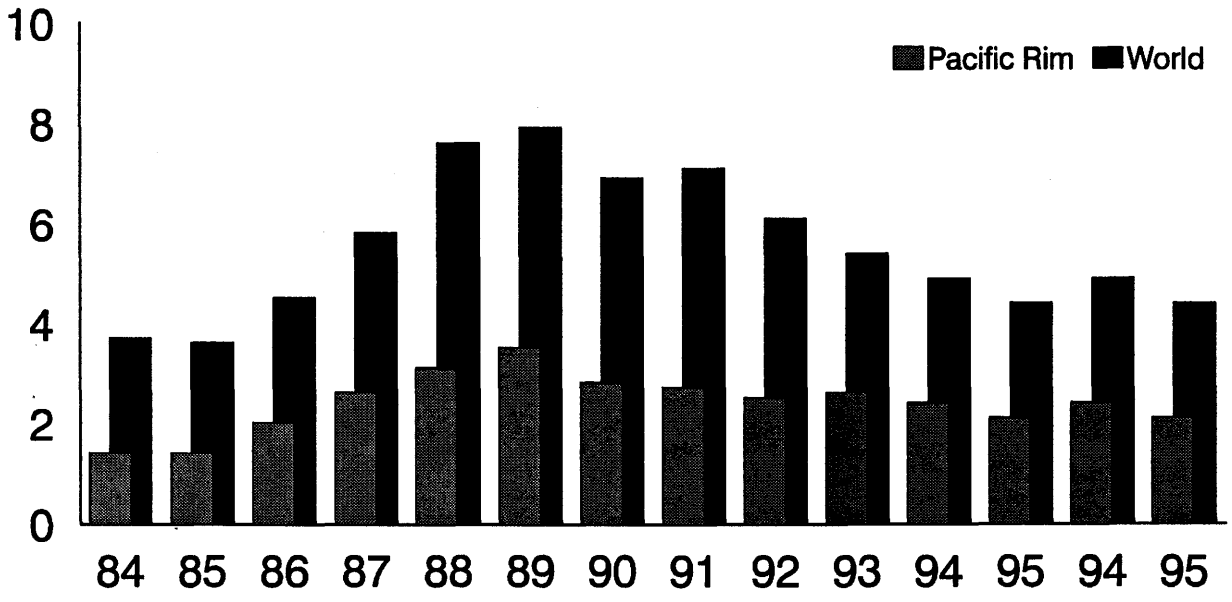

Figure 3.—Softwood lumber exports, in millions of cubic meters. Overall, volume has declined 42 percent from levels exported in the late 1980s (FAS 1996).

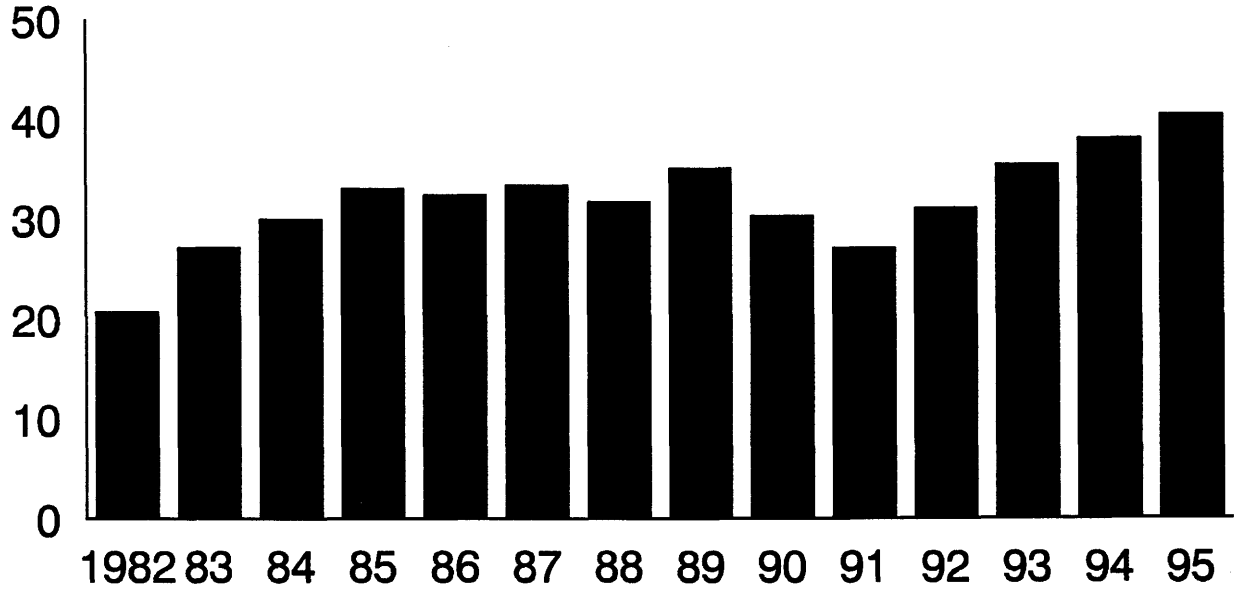

Figure 4.—Softwood lumber imports, in millions of cubic meters. Volume has increased by about 12 percent from levels imported in the late 1980s (FAS 1996).

with a similar number of housing starts, 38.1 million cubic meters were imported, an increase of 12% (Fig. 4) (WWPA 1995).

The steep decline in softwood volume exported and the steady increase in softwood volume imported should come as no surprise. Softwood harvests on Federal lands in the Douglas-fir subregion have declined by 86 percent from the levels of the late 1980s (Haynes, pers. comm.). In 1986, 3.14 billion cubic feet of softwoods were harvested in the Douglas-fir subregion, which was 27 percent of the U.S. total. In 1995, 1.49 billion cubic feet were harvested, or 23 percent of the U.S. total (WWPA 1995). By 2000, the total is projected to be 1.7 billion cubic feet, or 15 percent of the U.S. total (Haynes and others 1993).

It is clear that some portion of the wood that is no longer being harvested in the Pacific Northwest is being harvested somewhere else. Harvest levels in the Southern pine region have increased by about 400 million cubic feet since the mid-1980s, and now account for nearly half the softwood harvested in the United States. However, the South has not

fully made up the difference from the Pacific Northwest, and the amount imported has risen steadily through the 1990s (WWPA 1995). Since most of the wood imported is softwood lumber from Canada, it is likewise clear that the Canadian environment is now supporting some portion of the harvest pressure that used to be placed on American timberlands. The question then arises: is it morally right for environmentalists and others who would preserve American timberlands to shift that harvest pressure to other countries, namely Canada?

This is a ticklish question in a number of ways. Who are we to tell the Canadians how to manage their lands if they choose to harvest timber to satisfy the American market? And, if we decided we did have some sort of moral right to sanction the Canadians for the abuse of their environment, we'd run up against the philosophy of free trade promoted by the Administration. It is difficult to preach the virtues of free trade while erecting trade barriers designed to change behaviors; other countries might be tempted to reciprocate. At best they would correctly describe us as hypocrites.

In any case, it may not be necessary for us to scold the Canadians. Provinces such as British Columbia face many of the same issues as Washington, Oregon and Northern California, among them a large urban center full of active people who do not depend on timber revenues for their livelihoods, but do value forests managed for recreation, wildlife and aesthetics. Greenpeace was founded in Vancouver, and there have always been vocal critics of the province's annual harvest. Concerns have also arisen as to the sustainability and broader environmental impacts of timber management on the vast areas of public forest lands in Canada. A statement from the provincial government of B.C. (1994) noted that "...unless we change our approach [to forest management], the harvest could decline by 15 to 30 percent over the next 50 years." While the FEMAT report (1993), the 1993 RPA Timber Assessment (Haynes and others 1993), and other reports project a continuing supply of softwood timber from Canada, it may be wise for policymakers to consider other options.

Siberia may be one such possibility, and northwestern mill owners are already glancing avariciously overseas (Sleeth 1994a). Siberia holds 60 percent of the world's softwood timber supply (Backman and Waggener 1992). However, Siberian forests on average produce around 10 cubic feet per acre per year. Thirty to forty percent of that material is wasted as technology to use wood residues is lacking. Hence, 15 acres of Siberian forest would need to be harvested to produce as much wood as 1 acre of coastal Douglas-fir in the Pacific Northwest. If harvest is foregone on 100,000 acres in the Pacific Northwest each year to preserve it for spotted owls, 1.53 million acres would be required of the Siberian forest for the same harvest volume. Potentially, habitat losses in the Siberian forest would more than offset any habitat gains made in the Northwest. Additionally, the increased waste of mill residues and the increased hauling distances in the Russian Far East for delivery to markets consumes additional fossil fuel energy and increases the carbon dioxide emitted without producing products or energy value (Lippke 1992).

Since much of the Russian forest is boreal, regeneration may be difficult. Russian foresters may not be prepared to deal with artificial regeneration of thousands of acres. Furthermore, Russian forests are known to harbor the Asian gypsy moth and some 27 other species that may be damaging to North American forests should they be released when wood from Siberia is imported into this country (Goheen and Tkacz 1993; Campbell and Schlarbaum 1994). This prospect is alarming to me personally, since my research focus is on white pine blister rust, a pathogen that appears to have originated in Eurasia. Our ecosystems are centuries away from full recovery, and new disease and insect introductions may greatly compound our forest health problems.

At the same time as softwood imports are increasing, hardwood log and lumber imports are also increasing (FAS 1996). Now, it is important to put this in perspective. The volume of trade in these products is vastly less than in softwood products. Further, the balance of trade (exports minus imports) is positive: more is exported than imported. Nevertheless, the United States does buy an increasing volume of hardwood lumber from Canada, Brazil, Bolivia, Malaysia, Ecuador, and a number of other countries.

On the other hand, the balance of trade is negative for certain other hardwood products. The United States is importing more hardwood plywood and hardwood molding than it exports. According to Barbier and others (1994), the main wood product that the United States imports from the tropics is hardwood plywood, and America's main suppliers for tropical timber are Indonesia, Malaysia and Brazil.

The largest market in the world for tropical timber is Japan (Barbier and others 1994). While Japan has substantial timber resources, it imports almost 75 percent of the wood it consumes. Nearly all of the tropical timber Japan imports comes from Asia, primarily Malaysia and Indonesia. For the most part, tropical timber is imported to Japan in the form of logs, which are primarily converted into plywood. While hardwood plywood is not used for construction in North America, that is not the case in Japan. Hardwood plywood made from tropical timber is preferred over North American softwood plywood for concrete forms because it has no knots. It is also used to make furniture for the low-end market (Bevis 1995).

Here is the heart of the matter. Tropical forests are the most biologically diverse ecosystems on earth. The number of species that live in them has been variously estimated from 3 million to 30 million, and no one knows how many are at risk of extinction from logging and subsequent deforestation. What is known is that mature tropical forests are surprisingly unproductive. On average, they produce only between 5 and 35 cubic meters per hectare of merchantable wood (FAO/UNEP 1981). The reason for this is that much of the wood on any acre is too small, of the wrong species, and won't pay its way to the mill. For that reason, the first loggers in a virgin forest high-grade the stand, extracting perhaps one or two trees per acre (Bevis 1995). However, to get there they bulldoze a road, causing disturbance and edge effects. In

many parts of the world, these roads are subsequently used by small farmers who colonize newly accessible areas and clear the remaining forest for agriculture. Often deforestation is required for the farmer to gain land tenure (Barbier and others 1994).

Now, we can choose to scold Japan for its dependence on tropical timber. Again, we must deal with such ticklish issues as "do we have a moral right to tell anyone else what to consume?" If we decide that yes, we do have that right we run the risk of looking hypocritical. We may look considerably less hypocritical if we first consider our own consumption of imported wood from Canada and the costs to the Canadian environment. Additionally, we need to become active partners in multilateral organizations that seek to establish incentives for sustainable tropical (and, arguably, temperate) timber management. Finally, we may try to offer good alternatives to tropical timber rather than simply admonishing the Japanese for their destruction of tropical forests. However, if those alternatives include American softwoods, it may be difficult for the Japanese to make the switch from tropical timber if those alternatives have an uncertain future because of continued reductions in harvest levels.

Arguably, neither Canadian deforestation, Siberian regeneration, or Japanese tropical timber consumption are American problems. But if American consumption is driving the any of these processes, they are our problems. Even if it isn't, they are our problems if we consider ourselves citizens of the planet rather than narrow-minded regionalists. The rainforest on Borneo, oldest and second largest in the world, is home to the endangered orangutan. Environmentalists lay down in front of bulldozers to protect the spotted owls and "ancient forests" of the Pacific Northwest. Compared with this Malaysian rainforest, the forests of the Northwest began growing yesterday and the spotted owl is a recent arrival. If we are willing to chain ourselves to bulldozers to protect old growth in the Pacific Northwest, shouldn't we be willing to do the same for the ancient forests of Borneo? Or is the hidden agenda simply "not in my back yard?"

It is countries like ours, Japan, and the Western Europeans who are wealthy enough to resist the pressures to log our own lands indiscriminately and set forests aside as reserves. And the way that we accomplish that is, by and large, by importing wood from other countries and asking them to damage their ecosystems so that we can keep ours untouched. It's much like locating a landfill in another community that needs the money and is willing to put up with the smell.

OPTION FOUR: GROW OUR OWN WOOD

If demand is unlikely to fall, substitutes are environmentally unfriendly and imports damage the environment in other nations, one option remains: to grow the wood we need ourselves. Using genetically improved tree species coupled with intensive silviculture, we can meet our own needs for wood products. But we need to make it a policy issue and help the public realize the necessity for action.

What we need is a different way of looking at our wood. Every day, every man, woman and child on Earth consumes wood, just as they consume food and water. If we consider this wood as an item necessary for our survival, we may be able to take steps to ensure its supply.

Consider another product we cultivate, wheat. It is the staple food of the American diet, and we grow what is used here. However, I live in the Palouse region and I know the environmental price we pay for that wheat. A bushel of wheat equals a bushel of lost topsoil. But I hear very few people arguing that we should restore the Palouse - or the Great Plains - to their original condition. We need the wheat.

Wheat and trees are similar in other ways. Modern wheat varieties are the product of genetic improvement programs where strains were selected that are high-yielding and disease resistant. They are cultivated under specific growing regimes designed to maximize their growth potential. Together, genetics and cultivation techniques lead to phenomenal yields per acre, much more than the wild forebears of wheat.

In the same way, trees that are selected to be high-yielding and disease resistant have been developed. Intensive silviculture can be coupled with good genetics to establish high-yielding plantations that are much more productive in terms of cubic meters per acre per year than wild forests.

At the same time, just as not every acre of agricultural land is used for wheat, not every acre of forestland should be used for high-intensity plantation forestry. However, by establishing some proportion of our lands as plantations, it should be possible to relieve harvest pressure from many areas that are considered valuable for other reasons.

A case study with application to our situation:

In 1905, export of native woods, particularly of kauri and rimu, was an important component of the New Zealand economy. Annual cut peaked in that year and began a decline. A 1909 Royal Commission determined that changes in logging practices or milling technology couldn't reverse this decline. A 1913 Royal Commission found that New Zealand could not meet its anticipated domestic wood needs by selective cutting in its remaining native forest, and recommended that an aggressive program of intensive forest plantations be initiated. Thus began the world-famous New Zealand school of plantation silviculture. Today, New Zealand meets 100 percent of its net domestic wood needs from plantations, and about 30 percent of its original native forest is now in protected reserves. Furthermore, for every unit of wood used at home, another is shipped overseas. Many ships leaving New Zealand harbors display a green banner stating that the wood on board is helping to save tropical rainforests. Unlike the United States, most conservation organizations in New Zealand strongly support the plantation program, recognizing its part in saving both local and tropical native forests

This year in New Zealand, 247,000 acres will be replanted after harvest of plantations or will be newly established as

radiata pine plantations. Genetically improved stock will be used on much of this. A combination of healthier trees, faster growth and (perhaps most important) improved harvest index of these breeds will increase average harvest productivity of the previous plantation sites from about 385 cubic feet per acre per year to well over 430 cubic feet per acre per year. The newly established plantations are mostly on marginal farm and pastureland, and that change is from zero to over 400 cubic feet per acre per year (Libby 1994b).

In the Pacific Northwest, substantial increases in productivity are possible without importing exotic tree species. Coastal Douglas-fir, western hemlock, western white pine, and other species have the potential to grow over 400 cubic feet/acre/yr without the problems associated with exotic plantations (Hermann and Lavender 1990; Packee 1990; Graham 1990). At the same time, Americans can "have their cake and eat it too"—set aside large areas for the preservation of old growth habitat, recreational opportunities, etc. For that to occur, more wood must be produced on fewer acres. This is exactly what forest genetics and tree improvement programs strive to do (Daniels 1993).

Tree improvement programs are not a new concept in the United States. Many long-term investments have been made both by private industry and by the Forest Service. Cooperative programs have been developed, tests installed, and seed orchards established. Some intensive programs such as loblolly pine in the Southeast have realized first-generation gains of 12 percent in productivity and predict gains in excess of 40 percent over wild stands for advanced generations (NCSU 1996). At present, however, the National Forests are seriously cutting the funding for these programs. Reduced harvest levels and more partial harvests means fewer acres to be planted every year. Since the products of tree improvement programs are improved seedlings, it is difficult to justify expenditures for unnecessary seedlings.

Without tree improvement programs, certain species will become rare. In particular, the only headway that has been made against white pine blister rust in the West has come from selection and breeding for genetic resistance to the disease. In the future, coupling intensive silviculture with genetic resistance may make it possible to re-establish western white pine, sugar pine, and other white pines in their historic roles and frequencies.

The good news is that more wood **can** be grown without destroying natural forests in the process. By using tree improvement technology and intensive silviculture on a relatively small proportion of our forestland base, more wood could be produced on fewer acres, and the pressure to extend timber harvesting into forested areas that are ecologically sensitive or highly valued for other purposes could be reduced.

Jess Daniels, a forest geneticist in the spotted owl region, put it well. He said, "The bottom line is this: If we are going to continue using more and more wood, then we have a moral responsibility to grow more wood to meet that demand. By not striving to grow our own wood, we inevitably shift that burden to other nations and regions not able to do it as responsibly and sustainably as we do. That makes us a nation of hypocrites, preaching the virtues of environmental protection while encouraging other nations to disregard those virtues for our benefit." (Daniels 1993).

In this the day of ecosystem management, we know that ecosystems pay no attention to administrative or political boundaries. So if all of Earth is viewed as a mega-ecosystem, fragments can't be set aside in the United States without considering the consequences elsewhere. This global viewpoint has been lacking in the conservation dialogue. If policymakers can begin to "think globally" rather than just listening to those who "act locally," fragile forest ecosystems everywhere may be maintained for generations to come.

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Carbon Sequestration in Forests as a National Policy Issue

Linda S. Heath and Linda A. Joyce[1]

Abstract.—The United States' 1993 Climate Change Action Plan called upon the forestry sector to sequester an additional 10 million metric tons/yr by the year 2000. Forests are currently sequestering carbon and may provide opportunities to mitigate fossil fuel emissions in the near-term until fossil fuel emissions can be reduced. Using the analysis of carbon budgets based on forest inventories, we analyze the impact of forest management activities on carbon storage at the state and national level.

PROBLEM

Human activities have changed and are continuing to change the concentration and distribution of trace gases and aerosols in the atmosphere, and the amount, type, and distribution of vegetation on the Earth's surface. The cumulative influence of these activities on natural processes is cause for global concern. Atmospheric chemistry has been altered noticeably by the release of greenhouse gases such as carbon dioxide, methane, and nitrous oxide (IPCC 1995). When the atmospheric concentration of these gases increases, the result is an increase in the amount of solar and terrestrial radiation absorbed by the atmosphere. Thus, these gases essentially slow the release of surface generated heat from the Earth's atmosphere into space. The amount of warming is a function of the concentration of these greenhouse gases in the atmosphere and the ability of these gases to absorb solar radiation (radiative properties of the gases).

Atmospheric carbon dioxide concentration has increased from a pre-industrial 280 ppmv to 358 ppmv in 1994 (IPCC 1995). This increase is the result of fossil fuel emissions from industrial and domestic activities, and land-use conversions. Methane concentrations have gone from 700 ppbv in pre-industrial times to 1720 ppbv in 1994 as a result of the production and use of fossil fuel, and anthropogenic activities such as livestock production. Nitrous oxide concentrations have gone from 275 ppbv pre-industrial to 312 ppbv in 1994. The main sources are from agriculture and industrial processes. Carbon compounds containing flourine, chlorine, bromine, and iodine, known as halocarbons, act as greenhouse gases. Additionally, these gases react to thin the ozone layer which shields the Earth from harmful solar radiation. The emissions of halocarbons are expected to fall as a result of the Montreal Protocol international negotiations which were convened to address the loss of the ozone layer. Scientists generally agree that climate has changed over the last century and that a discernible human influence is seen in the basis for this change. The global mean surface air temperature has increased between 0.3 and 0.6 degrees C since the late nineteenth century (IPCC 1995).

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If the rate at which carbon dioxide is added to the atmosphere continued at the 1994 levels, for at least two centuries; the atmospheric concentration of carbon dioxide would reach 500 ppmv by the end of the twenty-first century. Predicting the future level of atmospheric carbon dioxide and its resulting impact on climate rests on assumptions about the future emissions of carbon dioxide, other greenhouse gases, and aerosol precursors, and the longevity of these emissions in the atmosphere. Using demographic, economic, and policy factors to establish different future scenarios, the IPCC (1995) projected emissions with the resulting carbon dioxide concentrations. The concentration of carbon dioxide by 2100 in all of the scenarios increases from 35 percent to 170 percent above 1990 levels. General scientific consensus is that, under a mid-range emission scenario and the effects of aerosols, the global mean temperature will increase by about 2 degrees C by 2100. Alternative emission scenarios result in temperature increases from 1 to 3.5 degrees C by 2100 (IPCC 1995). Stabilizing the concentrations of greenhouse gases would require large decreases in emissions. A number of carbon cycle models suggest the stabilization of atmospheric carbon dioxide concentrations at 450, 650, or 1000 ppmv could be achieved only if global anthropogenic carbon dioxide emissions drop to 1990 levels by, respectively, approximately 40, 140, or 240 years from now, and drop substantially below 1990 levels subsequently (IPCC 1995).

POLICY CONTEXT

Because of the possible dire consequences of climate change, nations are examining ways to control greenhouse gas emissions in the face of economic and population growth pressures. The most recent document describing U. S. policy and preferred actions concerning global climate change is The Climate Change Action Plan (CCAP) (Clinton and Gore 1993) and Technical Supplement (U.S. Dept of Energy 1994). This plan was written in response to the Framework Convention on Climate Change (FCCC), an agreement (with no international binding obligations) signed by the United States and over 50 other countries at the United Nations Conference on Environment and Development ("Earth Summit") in Rio de Janeiro, Brazil in June, 1992. The objective of the FCCC is to stabilize "greenhouse gas concentration in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system (Article 2, FCCC)" (Clinton and Gore 1993).

The United States Climate Change Action Plan describes actions which would help meet the FCCC objective by reducing greenhouse gas emissions to 1990 levels by the year 2000. Strategies in the United States focus on reducing the emissions in energy-related sectors of the economy such as transportation and manufacturing and in forestry, on increasing the amount of carbon taken up and stored by natural systems. The forestry sector is currently

sequestering more carbon than it emits, and is considered an area to provide opportunities to mitigate fossil fuel emissions in the near-term until ways to reduce fossil fuel emissions can be developed. Generally, activities that increase biomass on a site, such as tree planting, increase carbon sequestration, and activities that decrease biomass such as prescribed burning release carbon to the atmosphere.

For the purposes of comparison, all of the greenhouse gases are converted to a common unit, metric tons of carbon equivalent, by conversion factors based on radiative forcing. The 1990 U.S. greenhouse gas emissions were 1,462 million metric tons of carbon equivalent (MMTCE) assuming forests were storing 130 MMTCE. By 2000, U.S. greenhouse gas emissions are projected to be 1,568 MMTCE assuming a forest sink of 137 MMTCE. Actions by the year 2000 must reduce expected U.S. emissions by an estimated 108 MMTCE.

A number of actions are outlined for emission reductions in efficiency of energy use, energy supply actions, methane recovery and reduction strategies, and control strategies for halocarbons and nitrous oxide gas. Preferred actions in the building and transportation sectors include strategies to increase energy efficiency in residential and commercial buildings, reduce growing demand for vehicle travel, and increase the efficiency of generating and distributing electricity. In the CCAP, the forestry sector is called upon to sequester an additional 10 MMTCE (to 147 MMTCE) by the year 2000 by accelerating tree planting in nonindustrial private forests, encouraging forest management evaluation in nonindustrial private forests, and expanding programs to increase the recycling of wood fiber.

Using the carbon budget inventory approach, we examine the magnitude of some silvicultural activities in sequestering carbon at the scale of an individual state and at the national level.

CARBON BUDGET METHODS

A carbon budget (sometimes called carbon balance) shows the inventory of carbon in carbon pools and the balance of exchange between the pools. Pools represent the measurable compartments of carbon within the ecosystem. The rate of exchange between pools and between the pools and the atmosphere is called carbon flux. Budgets typically are based on inventory or field research data. Two approaches have been used to compute a budget for an ecosystem or forest stand. One approach computes carbon budgets for ecosystems in physiological terms, including photosynthesis, respiration, and allocation (which refers to the relative amount of carbon stored in specific plant structures) using daily or monthly time steps (McGuire and Joyce 1995; VEMAP members 1995). Generally, the models producing these budgets are called process models, as they describe the processes underlying the system under study. The models are quite useful for investigating certain aspects of carbon budgets such as how the effects of elevated carbon dioxide and altered temperature and precipitation will affect ecosystem function and thereby carbon storage (Melillo et al. 1995). However, these models generally focus on pristine conditions rather than the existing vegetation inventoried in forest inventories and managed through silvicultural activities.

The second approach, the focus of this paper, uses commonly collected forest inventory data, linked to forest tree growth and yield functions and converted to tree carbon using conversion factors (Heath and Birdsey 1993). Carbon in other ecosystem components, such as litter layer, is represented by empirical equations based on site-specific information from ecological studies. This approach may be applied at the stand, forest, state, or regional level, and maybe used to develop carbon estimates over stand age.

An example stand-level carbon budget showing carbon over stand age is given in Figure 1. This budget was calculated for average Douglas-fir stands in the northern Rocky Mountains using average regional inventory data (see Woudenberg and Farrenkopf 1995). The stand was naturally regenerated following a clearcut. At that time, the carbon in trees is very low and over time, gradually increases to be greater than the carbon in the soil.

Using the inventory approach, we can represent the storage of carbon in forests as:

$$C_t = T_t + FF_t + U_t + S_t, \text{ with } T_t = V_t * CF$$

where C_t = total carbon in the forest, T_t = the amount of carbon in trees, aboveground and belowground, FF_t = carbon in the forest floor, U_t = the amount of carbon in the understory, S_t = the amount of soil carbon in the forest, and V_t = volume of trees, all at time *t*. CF is the conversion factor which converts volume in trees to carbon. Sometimes two conversion factors are needed: one to convert merchantable volumes to total tree biomass, and a second to convert total tree biomass to carbon. The tree component includes all above and below ground portions of all live and dead trees including the merchantable stem; limbs, tops, and cull sections; stump; foliage; bark and rootbark; and coarse tree roots (greater than 2 mm). Forest floor is all dead organic matter above the mineral soil horizons, including litter, humus, and other woody debris. Understory vegetation includes all live vegetation except that defined as live trees. The soil carbon includes all organic carbon in mineral horizons to a depth of 1 meter, excluding coarse tree roots. Common units for reporting carbon in vegetation biomass are million metric tons (MMT=teragrams=10^{12} grams), and billion metric tons (petagrams=10^{15} grams).

Carbon flux can be calculated as:

$$F_p = C_t - C_{t-1}$$

with F_p = carbon flux for period *p*. Carbon flux is expressed on an annual basis by dividing F_p by length of period. Fluxes could also be examined for specific tree-related inventory components, such as growth, or mortality.

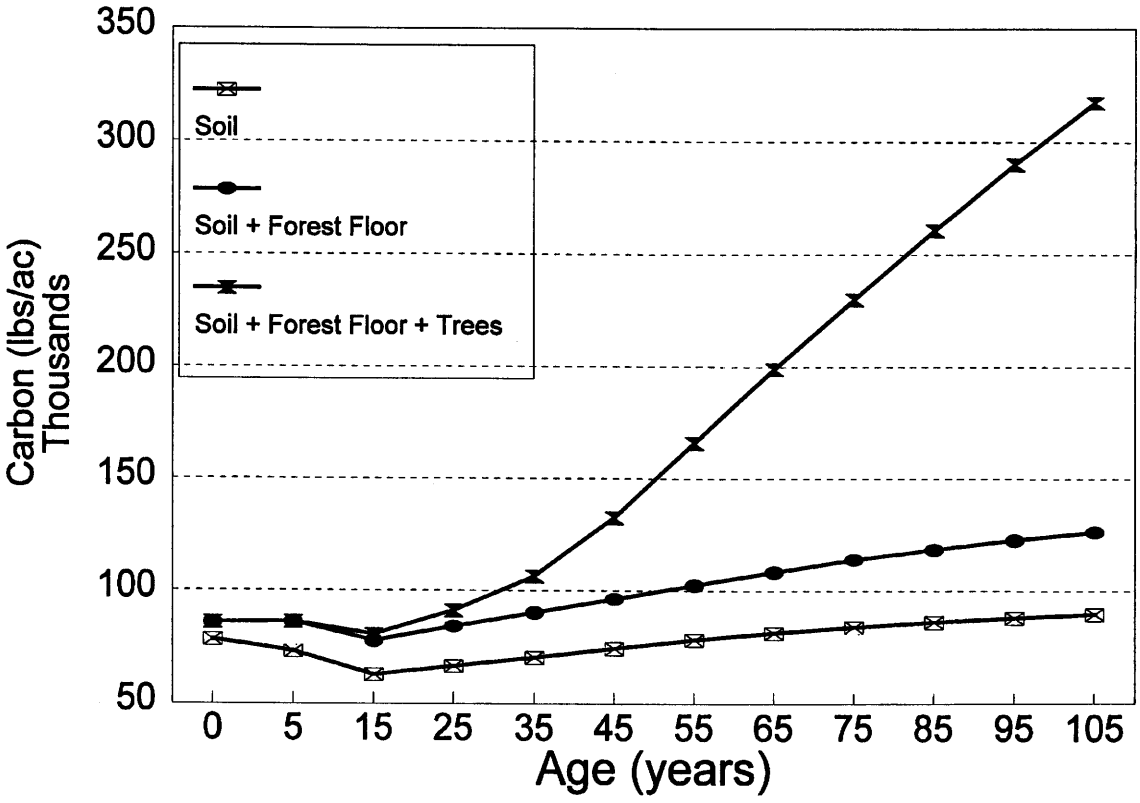

Figure 1.—Carbon changes over time for average Douglas-fir stands in the northern Rocky Mountains.

ESTIMATING CARBON ON TIMBERLANDS: IDAHO CASE STUDY

Carbon inventory

Idaho has 21.8 million acres of forestland. Within this acreage, 14.5 million acres feature forests defined as timberlands with tree growth greater than 20 cu ft/ac/yr and that are available for harvest (Birdsey 1992). This acreage is spread across public (11.2 million acres) and private (3.3 million acres) ownership. We estimate carbon inventory for the state, followed by an analysis of how various events such as fire or harvests contribute to carbon flux at the State level.

Birdsey (1992) computed the carbon stored at the State level from inventory data available for Idaho. Using the following equation:

$$C_t = T_t + FF_t + U_t + S_t,$$

$$1{,}466{,}560 = 603{,}299 + 215{,}100 + 10{,}659 + 637{,}502$$

Units are in 1,000 metric tons. The 1.47 billion metric tons of carbon stored in the Idaho forests represents about 4 percent of the carbon in conterminous U.S. forests. In the Idaho forests, about 41 percent of the stored carbon is in trees, 43 percent is in soil, 15 percent is in the forest floor and 1 percent is in understory vegetation.

Carbon flux and Components

Carbon flux in aboveground tree biomass can be calculated using appropriate conversion factors and standing inventories at two points in time. Merchantable volume is reported by forest type by State in reports such as Powell et al. (1993). The understory and forest floor components are small relative to the carbon stored in trees and assumed not to contribute to large changes in carbon flux from forests. Little is known about belowground tree carbon component especially in its response to disturbance, and this component was not included in the following analyses.

Because softwoods are approximately 98 percent of the volume in Idaho, only softwood conversion factors were used. An average conversion factor was calculated by weighting the average carbon by forest type by the amount of land area in forest types. For aboveground merchantable volume conversion to carbon, the conversion factor is 5.6829 kg C/cu ft. To convert to total above-ground carbon, merchantable cu ft volume must be multiplied by 10.7861 kg C/cu ft to account for branches, leaves, and bark.

The net volume of growing stock on timberland in Idaho was an estimated 33,001 million cubic feet in 1992 (Powell et al. 1993), and 32,600 m cu ft in 1987 (Waddell et al. 1989). Annual carbon flux is then (401,000 cu ft * 10.7861 kg C/ cu ft)/5 years = 0.8 MMT/yr. National forest inventory estimates were not updated over this period so this increase

represents volume increases only on private timberlands in Idaho, and as such, is a conservative estimate of the volume change in this time period.

Components of inventory, such as carbon in growth and removals, may be calculated in a similar way. The annual growth in 1991 is reported as 728,705 cu ft/yr, removals 333,015 cu ft/yr, and mortality is 182,614 cu ft/yr (Powell et al. 1993). Growth and mortality are average annual estimates calculated from periodic inventories, and removals are based on timber products output surveys and State harvesting reports. The privately-owned timberlands in Idaho were surveyed in 1981 and 1991; the dates of inventories on other ownerships vary. Net annual growth is reported as the increment of net volume of trees at the beginning of the specific year surviving to its end plus the net volume of trees reaching the minimum size class during the year. Because this volume estimate does not include branches, bark on, or leaves, growth is multiplied by 10.7861 kg C/cu ft to produce carbon growth increment. Removals are the net volume of trees removed from the inventory during a specified year by harvesting, or cultural operations such as timber stand improvement. Removals are converted from cu ft to kg C by multiplying by 5.5829 kg C/cu ft. The amount of carbon going into the logging debris pool is the difference between total carbon in removals and merchantable carbon removals. On timberlands, mortality is reported as the volume of sound wood in trees that died from natural causes during a specified year. Because this estimate should include branches, bark, or leaves, carbon in annual mortality is computed by multiplying annual mortality in cu ft by 10.7861 kg C/cu ft.

Table 1.—Estimated annual C flux by forest change or disturbance for Idaho.[a]

Type of change	C flux (MMT/yr)
Net Growth	7.8
Removals	-1.9
Logging debris	-1.7
Mortality	-2.0[b]
Wildfire	-2.6[c]
Probable land use	-0.2[d]

[a]See text for interpretation. Net growth is equivalent to total carbon flux between inventories.
[b]Assumes all carbon is lost from tree when mortality occurs.
[c]Assumes wildfire burns 58,343 hectares on average, and releases 44.8 MT/ha. (Assumes fires consume 30 percent of carbon in trees, all forest floor, and down and dead debris; 68.3 MT/ha in trees and 24.36 MT/ha in the forest floor).
[d]Assumes loss of 4,858 ha/yr (12,000 ac/yr) from timberland, with 46.3 MT/ha/yr released.

Inventory estimates do not report losses to prescribed fires or wildfires explicitly. Wildfires burned 106,164 ha (262,241 acres) annually on average in the period 1984-1990 on 15.7 million ha (38.8 million acres) of both forested and nonforested lands in Idaho (U.S. Department of Agriculture, Forest Service 1992). Assuming the number of acres of forested land burned in proportion to the ratio of forested land to nonforested land burned, on average wildfires burned 58,343 ha (144,116 acres) on forestland annually over this period. Average carbon in Idaho in trees on forestland is 68.3 MT/ha (Birdsey 1992).

Land use changes can alter the amount of carbon stored on timberlands. We assume a loss of 4,858 ha/yr (12,000 ac/yr) (Powell et al. 1993) from timberlands with 46.33 MT C/ha/yr released. This land is being used primarily for homes, roads, vacation or second homes, and pasture or crop agriculture (Ralph Alig pers. comm.).

Annual carbon flux for various forest activities or changes are listed in Table 1. A positive estimate indicates that carbon is removed from the atmosphere and sequestered in the forest; a negative estimate indicates that carbon is released into the atmosphere from the forest. Note that net growth is equal to the carbon increment between two successive inventories. In this case, an additional 7.8 MMT/yr is being sequestered. Potentially, if there were no removals, mortality, wildfires or land use changes, the annual carbon flux for Idaho would be 16.2 MMT/yr. The magnitudes of carbon flux from the activities in this State are quite large compared to 10 MMT/yr, the amount of carbon the 1993 Climate Change Action Plan requested from the U. S. forest sector. With magnitudes like these, proposed changes in activities that result in a 1 MMT/yr difference at the State level could be considered noticeable at the national level. Based on estimates used here, activity changes that would affect carbon sequestration by 1 MMT are: 92,712,000 cu ft growth or mortality (in other words, increasing or decreasing growth by 92,712,000 cu ft would increase or decrease carbon sequestration by 1 MMT), 104,747,000 cu ft removals (includes above-ground logging debris carbon flux), change in wildfire of 22,300 ha (55,100 ac), and a change in land use of 21,584 ha (53,313 ac).

Activities altering the carbon in the forest floor could also be of a magnitude to be considered noticeable. An average hectare of forestland in Idaho contains 26.7 metric tons of carbon in the litter layer (Birdsey 1992). Based on estimates from Brown and See (1981), about 19.7 metric tons/ha downed dead fuel would accumulate in mature forests, primarily in absence of harvesting and thinning. Activity changes that would release 1 MMT of carbon include removing the forest floor layer on 41,050 ha (101,400 ac) or removing dead, down woody fuels in mature forests on 50,800 ha (125,381 ac).

CARBON BUDGET AT THE NATIONAL LEVEL: UNITED STATES CASE STUDY

The state level analysis did not consider the role that economics would play in these timber management decisions or how climate change would affect the storage of

carbon and carbon flux. The role that economics might have on these timber management decisions can be addressed by placing the carbon calculations in the context of the national timber policy models used by the Forest Service. Climate scenarios and ecological models can be used to bring into these timber policy analyses the potential effect of climate change.

Birdsey (1992) estimated carbon storage and flux for all forest land classes and all 50 States using the national compilations of forest inventory statistics (Cost et al. 1990; Powell et al. 1993; Waddell et al. 1989) supplemented with information from ecosystem studies. Biomass carbon is a function of inventory volume calculated from ratios and conversion factors based on the high correlation between volume and biomass (Cost et al. 1990). Carbon in the soil and the litter is estimated with models that relate organic matter to temperature, precipitation, and age class, using data from ecosystem studies compiled by various authors. The periodic inventories conducted in the United States allow the computation of carbon flux over time.

Table 2.—Carbon flux from aboveground forest component for private timberlands in the United States for the baseline scenario and two alternative carbon sequestration scenarios: tree planting and increased recycling. Positive flux values indicate a storage of carbon. The flux values in parentheses indicate negative fluxes or the release of carbon into the atmosphere.

Year/Period	Base Run	Planting M/R	Recycling
	---------- *Million metric tons* ----------		
Storage:			
1990	7,838	7,838	7,838
2000	8,266	8,218	8,288
2010	8,554	8,498	8,674
2020	8,610	8,631	8,843
2030	8,516	8,547	8,836
2040	8,303	8,354	8,698
	----- *Million metric tons per year* -----		
Flux:			
1990-2000	43	38	45
2000-2010	29	28	39
2010-2020	6	13	17
2020-2030	(9)	(8)	(6)
2030-2040	(21)	(19)	(14)

Approximately 54.6 billion metric tons of organic carbon are found within the forest ecosystems of the United States (Birdsey and Heath 1995), representing 5 percent of the world's forests (Dixon et al. 1994). Most of the forest carbon is found in the soil component. Trees, including the roots, account for 29 percent of all forest ecosystem carbon (Birdsey and Heath 1995). Fifty percent of this represents growing stock live tree section, another 30 percent is in other live solid wood above the ground, 17 percent is in the roots, 6 percent is in standing dead trees, and 3 percent is in the foliage. The proportion of carbon in the different components varies by region and reflects the temperature and precipitation of each region. Larger amounts of soil carbon are found in cooler and wetter regions. For example, over 75 percent of the total carbon in Alaska is in the soil. The Southeast and South Central States have carbon evenly split between the belowground and aboveground components.

Carbon budgets were projected into the future using the FORCARB model (Plantinga and Birdsey 1993), linked to a forest sector modeling system (see Birdsey and Heath 1995). Together these incorporate the demand for wood products and its impact on harvesting and other management decisions on carbon storage by timber management type by regions in the United States. Carbon is accounted for in biomass, soil, and the litter layer including coarse woody debris. Carbon is also computed for wood removed during the harvest by four disposition categories: wood-in-use, landfills, wood burned for energy, and emissions. FORCARB uses estimates of forest inventory, growth, and removals for age class distributions within each timber producing region in the United States, from the ATLAS inventory model (Mills and Kincaid 1991), so the estimation of carbon storage for each projection period is a straightforward application of the carbon accounting model. Carbon flux is estimated as the average annual change between successive inventory projection periods.

A base scenario is constructed with assumptions about the economic future, such as per capita income, population growth, and energy prices. This base scenario assumes that climate will be unchanged from the historic patterns. For this analysis, only private timberland is considered, and only carbon in trees is presented here (Table 2). Under the base scenario, forests release more carbon than is stored in the aboveground tree biomass by the end of the 50 year projection period.

Two policy activities to sequester carbon in forests under the historical climate were analyzed using FORCARB. The planting scenario assumes a federally funded program to plant about 6 million acres of loblolly pine over the next decade in Oklahoma and Texas. The recycling scenario assumes a future in which the use of recycled fiber in paper and board production rises to 39 percent of total fiber furnished by 2040 (Haynes et al. 1995).

The recycling scenario sequesters more carbon in the aboveground portion of U.S. forests than the tree planting scenario, but this scenario does not reflect the entire carbon sequestration effects. In the tree planting scenario, more trees mean more wood is available for harvest at lower prices. The greater the harvests, the more carbon stored in

Table 3.—Cumulative disposition of carbon removed from private timberland in the baseline scenario.

Year	In Use	Landfill	Energy	Emitted	Total
			Million metric tons		
2000	744	0	488	191	1,424
2010	1,264	199	1,060	490	3,015
2020	1,706	468	1,690	873	4,738
2030	2,119	778	2,358	1,304	6,558
2040	2,502	1,119	3,064	1,794	8,479

wood products, or burned for energy. Recycling, on the other hand, tends to lead to lower harvests and less wood goes into the wood product stream. This phenomenon shows in the results in a comparison of the cumulative disposition of carbon removed from private timberland for the policy scenarios. By 2040, the cumulative total of carbon removed in the base scenario is 8,479 MMT (see Table 3), but the total removed in the recycling scenario is only 8,203 MMT, and the total removed in the tree planting scenario is 8,601 MMT.

These two scenarios do not include the belowground component in the future projection. About two-thirds of the historical positive flux of carbon in U.S. forests is in the soil component (Birdsey and Heath 1995). Our understanding of the soil carbon dynamics limits this and other analyses (U.S. EPA 1994).

The IPCC/OECD (1994) report recommends that countries not include the carbon stored in wood products in the carbon accounting analyses at the country level. These analyses have followed this procedure. However, nearly 30 percent of the wood harvested remains in use, in the base scenario, by 2040 (Table 3). In addition, large amounts are used by energy and less than 21 percent is emitted from the harvesting process. This suggests that these policy analysis estimates of carbon sequestration may be low.

Finally, these projections assume the historical climate. To examine the impact of potential changes in climate on carbon storage, three climate scenarios were imposed upon a forest productivity model. Changes in forest productivity were then imposed on the linked timber inventory-FORCARB modeling system (Joyce et al. 1995). The scenarios reflect productivity changes attributable to climate change. For this analysis, only timberland is considered, and only carbon in trees is presented. Projected carbon changes on private timberland from climate change over the 1990 to 2040 period are shown, along with the recycling and planting scenarios, in Figure 2. Under the historical climate, the projections for carbon storage on timberland show a decline of 21 MMT per year on timberland by 2040. Under the minimum change climate scenario, forests also release more carbon than they store in the aboveground component. Under the moderate climate change and the maximum change scenario, forests accumulate carbon. This increase under the moderate and maximum change scenarios represents only the increase in tree carbon because estimates of possible changes in other forest ecosystem components were not projected.

These scenarios suggest that management activities and climate change can have an impact on the amount of carbon stored on forest lands and that alternative forest activities could affect the carbon stored through 2040.

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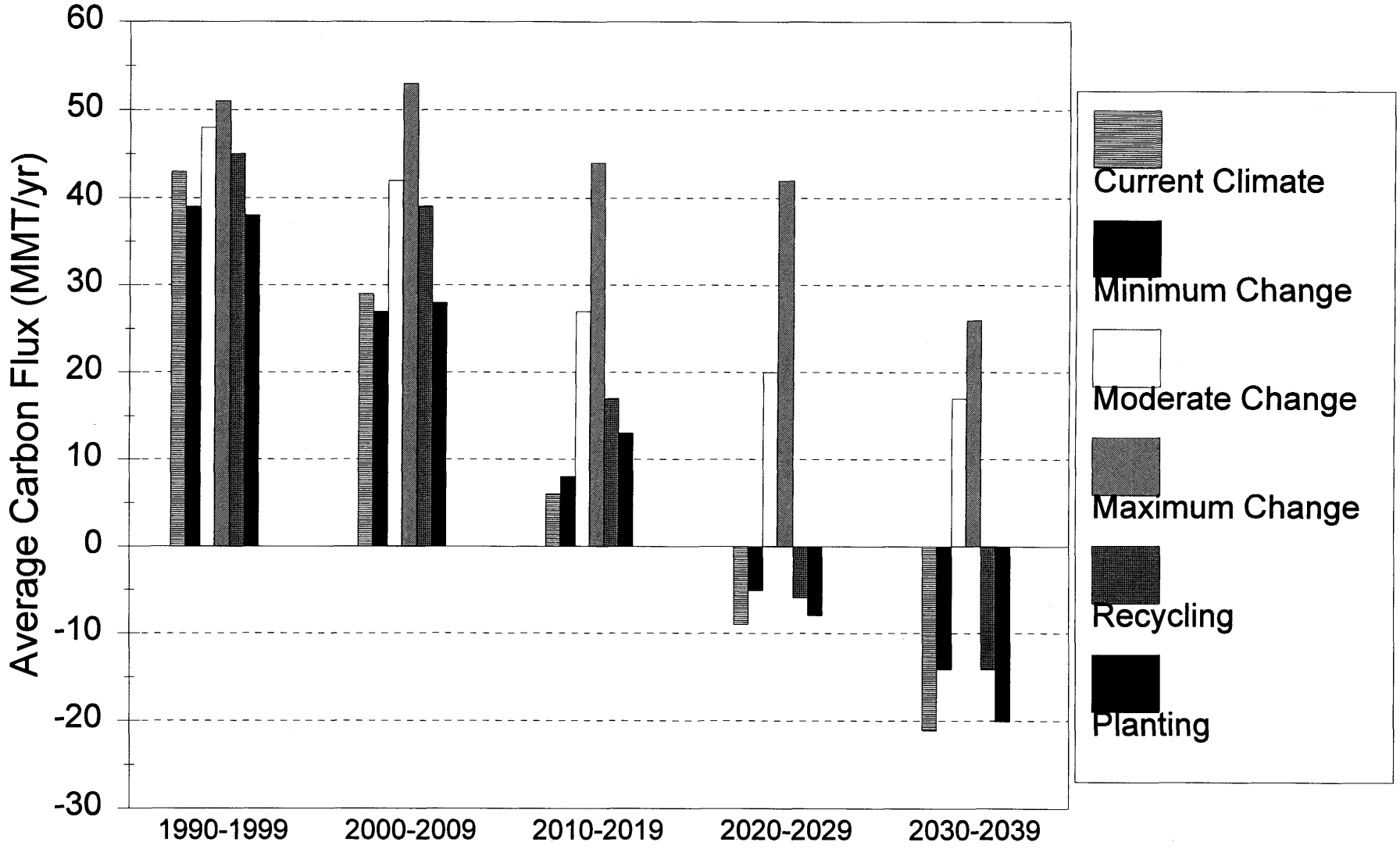

Figure 2.—Carbon flux for baseline, two alternative carbon sequestration scenarios, and three climate change scenarios.

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Plant Morphological Characteristics as a Tool in Monitoring Response to Silvicultural Activities

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Abstract. —Monitoring environmental change through documentation of species composition becomes problematic when compositional changes take several years to occur or simply do not occur following silvicultural treatment. Morphological characteristics (e.g., leaf area, node density, bud number) change in many plant species in response to factors such as light availability, soil compaction, and organic matter removal. As a monitoring tool, morphological characteristics: 1) detect plant responses soon after treatment, 2) reveal underlying factors that produce changes in plant condition and composition, 3) allow prediction of short-term growth response and long-term forest development, and 4) may aid in communicating effects of silvicultural treatments.

INTRODUCTION

Information on changes in environmental factors and plant species brought about by silvicultural treatments is essential for communicating the beneficial or detrimental effects of a given treatment, and for selecting appropriate future management options. In the past, monitoring efforts tended to focus on the effects of silvicultural treatments on commercial tree species, game species of wildlife, and watershed hydrology. Effects of current silvicultural practices on non-commercial plant species, non-game wildlife, and ecological interactions within managed ecosystems are less well understood. As demand grows for simultaneous yields of forest products and a multitude of other forest values, the need for information on how silvicultural options affect all categories of species and their interactions within managed stands will increase. This information will be vital for communicating how silviculture can meet the demand for multiple forest values and for evaluating the success of various treatments.

Changes in the composition of tree, shrub, and herb species in the understory are frequently used by land managers to monitor changes in the environment and plant species response following the implementation of silvicultural practices. Documentation of compositional changes allows managers to infer impacts of silvicultural treatments on timber species as well as shrubs and herbs, some of which may be threatened, endangered, or produce special forest products. This method, however, has several limitations. *Merely documenting changes in species composition does not identify the underlying factors responsible for the loss or gain of plant species on a site.* Without this knowledge, it is difficult to fine-tune silvicultural practices in order to prevent the loss of certain species or encourage colonization by others. A second limitation is that compositional changes may occur very slowly following treatment. Thus, it may be necessary to wait several years to assess the effect of a given treatment. Populations of certain species may persist for long periods, despite the fact that they are declining and will eventually be replaced by better-adapted species. Finally, species composition may not change at all following treatment. Due to the innate plasticity in many plant species, individual species may respond by changing their growth form and morphology. These changes can be quite subtle or dramatic (depending on the species and type of silvicultural treatment), and can be correlated with light quantity and quality, water availability, and soil physical and chemical properties.

CHANGES IN MORPHOLOGICAL CHARACTERISTICS

Following a change in environmental conditions, changes in morphological characteristics can occur from the scale of entire plants to the scale of individual leaves, buds, flowers, and fruits. Perhaps the most familiar morphological characteristics are those at the level of entire shoots such as live crown ratio, crown shape, and multilayer vs. monolayer distributions of foliage (Horn 1971; Kramer and Kozlowski 1979). Morphological characteristics of stems as well as entire shoots include length or height, seasonal patterns of internode lengths, node density, total leaf area, and the density and distribution of flowers, fruits, leaves and buds (Bonser and Aarssen 1994; Canham 1988; Dahlem and Boerner 1987; Huffman et al. 1994a; Sipe and Bazzaz 1994; Stafstrom 1995; Tappeiner et al. 1987; Wilson 1995). At smaller scales, differences can occur in the area, width, length, shape, orientation, and thickness of leaves, the size and shape of buds, and the size, shape and seed characteristics of fruits (Abrams and Kubiske 1990; Collins et al. 1985; Goulet and Bellefleur 1986; Harrington and Tappeiner 1991; Huffman et al. 1994a; Jurik 1986; Niinemets 1996; Waller and Steingraeber 1995). Morphology of underground parts important in vegetative reproduction also change with environmental conditions and can be predicted to some extent from above-ground morphology (Huffman et al. 1994a,b).

An entire tree, shrub, or herb can be considered as an array of repeating individual units or modules (Bell 1991; Harper 1977; Stafstrom 1995; Watson and Casper 1984; White 1979). Widespread differences exist in the overall

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morphological plasticity of species and their ability to modify certain types of modules due to differences in evolved strategies and evolutionary constraints (Abrams and Kubiske 1990; Ashton and Berlyn 1994; Goulet and Bellefleur 1986; Niinemets 1996; Pickett and Kempf 1980; Sipe and Bazzaz 1994). Thus, co-occurring species may respond quite differently to a given change in the environment. For example, on long-term soil productivity sites, we measured significant changes in the morphology of trembling aspen, *Populus tremuloides* Michx. , (Figure 1) and bracken fern, *Pteridium aquilinum* (L.) Kuhn (Figure 2), in response to soil compaction and organic matter removal, while no significant changes occurred in the measured morphological characteristics of co-occurring large-leaved aster, *Aster macrophyllus* L., or strawberry , *Fragaria virginiana* Mill.. Further, Abrams and Kubiske (1990) found that plasticity in leaf structural characteristics varied among 31 hardwood and conifer tree species in response to open and closed canopy conditions. Important trade-offs can exist between the ability to change morphological characteristics in response to environmental conditions and reproductive or mechanical requirements (Mattheck 1995; Waller and Steingraeber 1995). It is also possible for species to respond to an environmental change through physiological rather than morphological adjustments (Collins et al. 1985).

RELATIONSHIPS BETWEEN MORPHOLOGY AND ENVIRONMENTAL CONDITIONS

Due to the strong influence of environmental conditions on plant development in many species, morphological characteristics can be correlated with a number of above- and below-ground factors. Leaf weight/area ratio was significantly higher in open locations than in understory locations in 23 of 24 hardwood species studied (Abrams and Kubiske 1990). We found similar increases in leaf weight/area ratio with more gradual decreases in canopy cover in northern hardwood stands representing uncut, 75% cover, 50% cover, and clearcut conditions (Figure 3). The steady increases in leaf weight/area ratio from uncut to clearcut conditions in some species (Figure 3) suggests that it may be possible to relate leaf weight/area ratio to more subtle differences in canopy cover than those that we studied. In addition to morphological responses to fine-scale differences in conditions, it is possible to relate changes in plant morphology to conditions that change over short time intervals. Good relationships have been demonstrated between climatic variables such as previous day incoming solar radiation and daily increases in the length of the shoots of red pine, *Pinus resinosa*, Ait., and aspen (Perala 1983). With respect to above-ground responses to below-ground conditions, we found significant changes in stipe length and frond length of bracken fern in response to soil compaction and organic matter removal on long-term soil productivity sites established on both fine- and coarse-textured soils (Figure 2).

RELATIONSHIPS BETWEEN MORPHOLOGY, PHYSIOLOGY, AND PLANT CONDITION

In addition to serving as indicators of environmental conditions, certain morphological characteristics also indicate current physiological status. Live crown ratio in trees, for example, provides an indication of the amount of photosynthesizing tissue relative to respiring tissue (Kramer and Kozlowski 1979). In general, the greater the proportion of photosynthesizing tissue to respiring tissue, the greater the amount of photosynthate available for growth. Leaf weight/area ratio is an indicator of the amount of photosynthesizing mesophyll tissue in a leaf, which, in turn, influences the leaf's photosynthetic capacity (Jurik 1986). Insights on current plant condition gained from examination of morphological characteristics, such as the differences in form between vigorous and suppressed trees, can be used to predict future success of a plant. It is also possible to directly relate future success to morphological characteristics. For example, the number of interwhorl buds was strongly related to the vigor of Douglas-fir, *Pseudotsuga menziesii*, (Mirb.) Franco, seedlings (Tappeiner et al. 1987), and the length of 1-year-old needles on Ponderosa pine, *Pinus ponderosa*, Dougl. Ex Laws., var. *ponderosa*, seedlings was an indicator of future height and diameter growth (McDonald et al. 1992).

A PROPOSED METHOD

Our goal is to develop a method in which morphological characteristics are used as indicators of environmental conditions resulting from silvicultural treatment. The first step in developing this method would be to select appropriate plant species. These species: 1) must exhibit plasticity in their morphology and physiology, 2) should occur over a broad geographic region and occupy as large a range of habitat types and stand conditions as possible, and 3) should exhibit changes in morphological characteristics that are easily measured. The next step would be to link changes in morphological characteristics with known changes in environmental conditions such as temperature, humidity, light, and soil moisture that follow silvicultural treatment. When relationships are identified, their quantity and quality should be examined across regions and habitat types. For example, in our work on long-term soil productivity sites, we found significant differences in morphological characteristics of trembling aspen in response to compaction and organic matter removal on fine-textured soils in Upper Michigan, but not on coarse-textured soils in Lower Michigan. The final step in developing the method would be to identify its limitations. Potential problems include genetic variation within species and variation in morphological characteristics within individuals due to developmental stage or age (Coleman et al. 1994; Hanson et al. 1986). Some morphological characteristics such as leaf weight/area ratio and node density vary substantially within individuals. Standard sampling positions for these characteristics would be

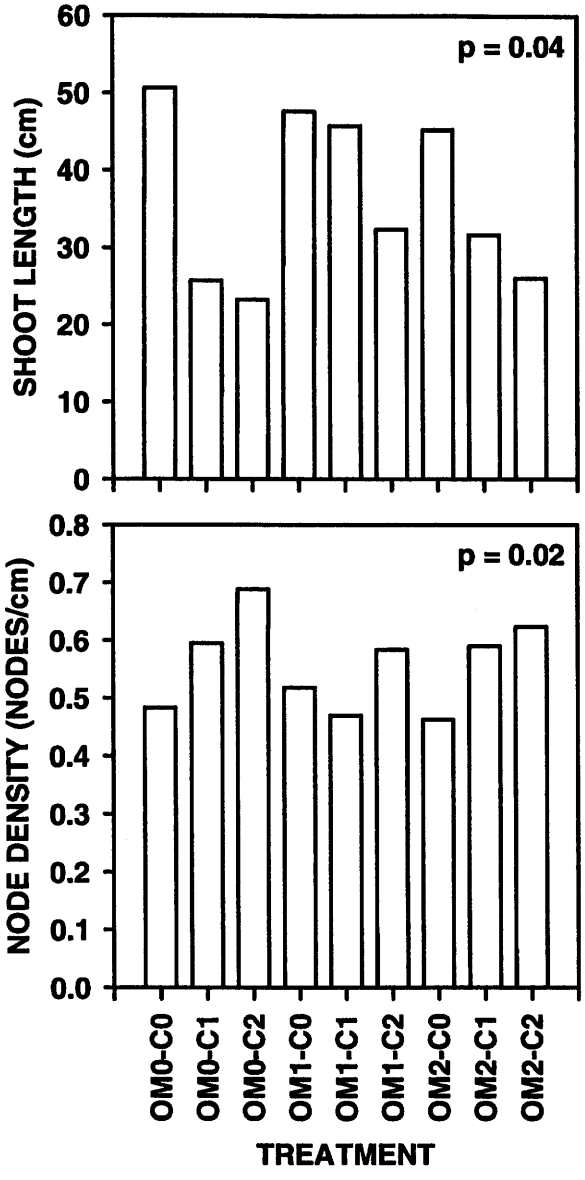

Figure 1.—Morphological differences in current-year shoots of equal-aged trembling aspen in response to combinations of organic matter removal and compaction treatments on a long term soil productivity site established on the Ottawa National Forest. Treatment codes are as follows: OM0 = no organic removal, OM1 = moderate organic matter removal, OM2 = severe organic matter removal, C0 = no compaction, C1 = moderate compaction, C2 = severe compaction. All plots were logged prior to receiving organic matter and compaction treatments. Significant differences in shoot dry weight, shoot diameter, and leaf dry weight of trembling aspen were also found among treatments on this site.

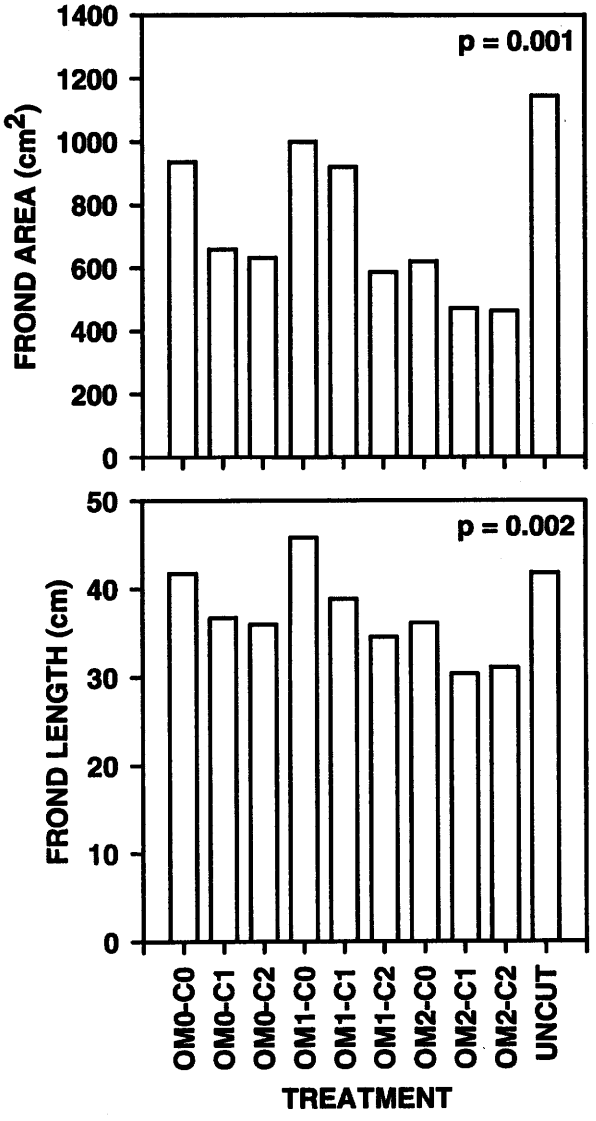

Figure 2.—Differences in morphological characteristics of bracken fern in response to combinations of organic matter removal and compaction treatments on a long term soil productivity site established on the Ottawa National Forest. Treatment codes as in Figure 1. Uncut = no organic matter removal, no compaction, and no cutting. Significant differences in stipe length and frond dry weight were also found on this site. Significant differences in stipe length and frond length in bracken fern were found in response to similar treatments on a long term soil productivity site on coarser-textured soils on the Huron-Manistee National Forest.

necessary. Another problem related to development is that plants originating from vegetative reproduction may differ from those developing from seed during the early stages of development. These potential problems can be overcome, however, with careful choice of indicator species and sampling conditions.

CONCLUSIONS

Properly used, morphological indicators could be a valuable addition to the land manager's tool kit for monitoring changes brought about by silvicultural practices. Morphological characteristics have the advantages of: 1) allowing rapid assessments of the effects of silvicultural treatment, 2) revealing the underlying environmental factors responsible for changes in the condition of plants following treatment, 3) providing indications of the physiological status and condition of individuals, and 4) providing information for the prediction of the future status of plant populations and forest development. As a communication tool, the more easily-observed changes in morphological characteristics and their significance could be pointed out on field trips to illustrate the benefits of silvicultural treatments. Due to their direct link with the current growth and vigor of species, certain morphological characteristics may be a more effective communication tool than attempting to describe the past or predicted future condition and occurrence of species on a site.

ACKNOWLEDGMENT

We thank Edward Gritt and Adam Wiese for their help in obtaining morphological measurements, and Richard Dickson for reviewing an earlier version of this manuscript.

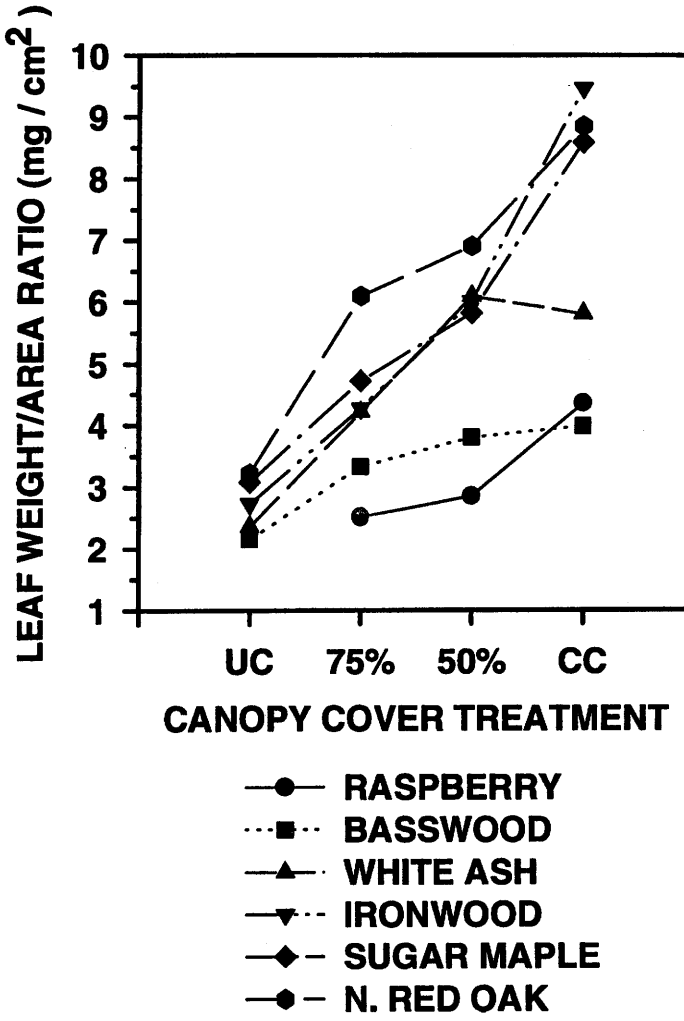

Figure 3.—Differences in leaf weight/area ratio of raspberry and five hardwood species across adjacent northern hardwood stands thinned and clearcut to achieve different amounts of canopy cover. Treatment codes are as follows: UC = uncut (control), 75% = 75% canopy cover, 50% = 50% canopy cover, and CC = clearcut.

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Monitoring the Effects of Partial Cutting and Gap Size on Microclimate and Vegetation Responses in Northern Hardwood Forests in Wisconsin

Terry F. Strong, Ron M. Teclaw, and John C. Zasada[1]

Abstract.—Silviculture modifies the environment. Past monitoring of silvicultural practices has been usually limited to vegetation responses, but parallel monitoring of the environment is needed to better predict these responses. In an example of monitoring temperatures in two studies of northern hardwood forests in Wisconsin, we found that different silvicultural practices modified the environment significantly. Temperatures become more extreme as openings in the forest canopy become larger. Temperatures in some cases reached lethal levels. By monitoring the microenviroment along with vegetation responses to different silvicultural practices, we can learn how to grow specific plants or plant communities by adapting the current silvicultural guides.

INTRODUCTION

Silvicultural systems for northern hardwood forests in the upper Great Lakes region include both even- and uneven-age management. The guidelines for tending these forests and the results of their use are well-established (Arbogast 1957; Burns and Honkala 1990; Erdmann 1986; Niese et al. 1995; Strong et al. 1995; Tubbs 1977) and have been used over thousands of acres of public, private and industrial forest lands for several decades. These guidelines cover a continuum of forest overstory conditions from clearcuts to single tree selection.

Because these guidelines have been used extensively and results assessed over many combinations of stand and site conditions, it is now recognized that some adaptations are needed to ensure that tree and other plant species composition, distribution, and growth can be managed to meet timber production, biodiversity, wildlife habitat, aesthetic, and other management objectives. The current guidelines tend to favor the establishment of sugar maple, meeting some management objectives but not others. Furthermore, recent studies in northern hardwoods have substantiated the observation that single and multiple tree gaps created by wind, insects, disease and other factors are of primary importance in maintaining species composition and that incorporating gaps into silvicultural systems for northern hardwoods is important for many management objectives (Canham and Loucks 1984; Erdmann 1986; Frelich and Lorimer 1991; Lorimer and Frelich 1994).

Monitoring the physical environment following silvicultural treatments provides information on the immediate changes in light quantity and quality, soil and air temperature, wind, and other factors. This information describes the immediate change in the availability of resources and the important initial potential for establishment and growth of species with varying requirements for light, water, and nutrients. Longer term monitoring of these variables allows silviculturists to assess change as the forest develops following a prescribed silvicultural treatment and perhaps more importantly to correlate the composition and growth of trees and associated plants with the availability of resources as affected by the treatment.

The objective of the work described in this report, is to describe the effects of a range of different-size, purposefully created canopy gaps and stand level canopy conditions on the temperature regime of managed stands of northern hardwoods in northern Wisconsin. We recognize that temperature interacts with light, water and nutrient availability to provide the resource environment for plant growth. However, temperature—both extreme events (for example frost) and more general growing season conditions—is important in these forests. By itself, temperature affects the physiological processes that result in the phenological and growth patterns that we observe and measure. Compared to the other resources, temperature is relatively inexpensive to measure and thus point-to-point variation is easier to illustrate than similar scale variation in the other resources.

Here we report brief results of two studies to describe how by monitoring microclimate, we can better communicate the values and benefits of silviculture to landowners. Our work builds on the more general work described in Geiger (1965) and earlier work in these forests (Ringger 1972; Ringger and Stearns 1972).

STUDIES

Partial Cutting

We are conducting this study to document meteorological/environmental conditions, and to correlate plant composition and density to the specific conditions rendered by the various partial cutting treatments. The study consists of four 8-ha blocks each thinned to a different overstory density including a clearcut, 50 percent crown cover, 75 percent crown cover and a control.

Meteorological monitoring stations were installed in the center of the clearcut, 50 percent crown cover, and control blocks in 1993. Air and soil temperature profiles are continuously monitored at 10, 2, 1, 0.75, 0.5 and 0.25 m aboveground and 0.05, 0.1, 0.2, 0.5, and 1.0 m belowground.

Canopy Gap Study

We are conducting this study to understand the function and dynamics of canopy gaps in northern hardwood ecosystems,

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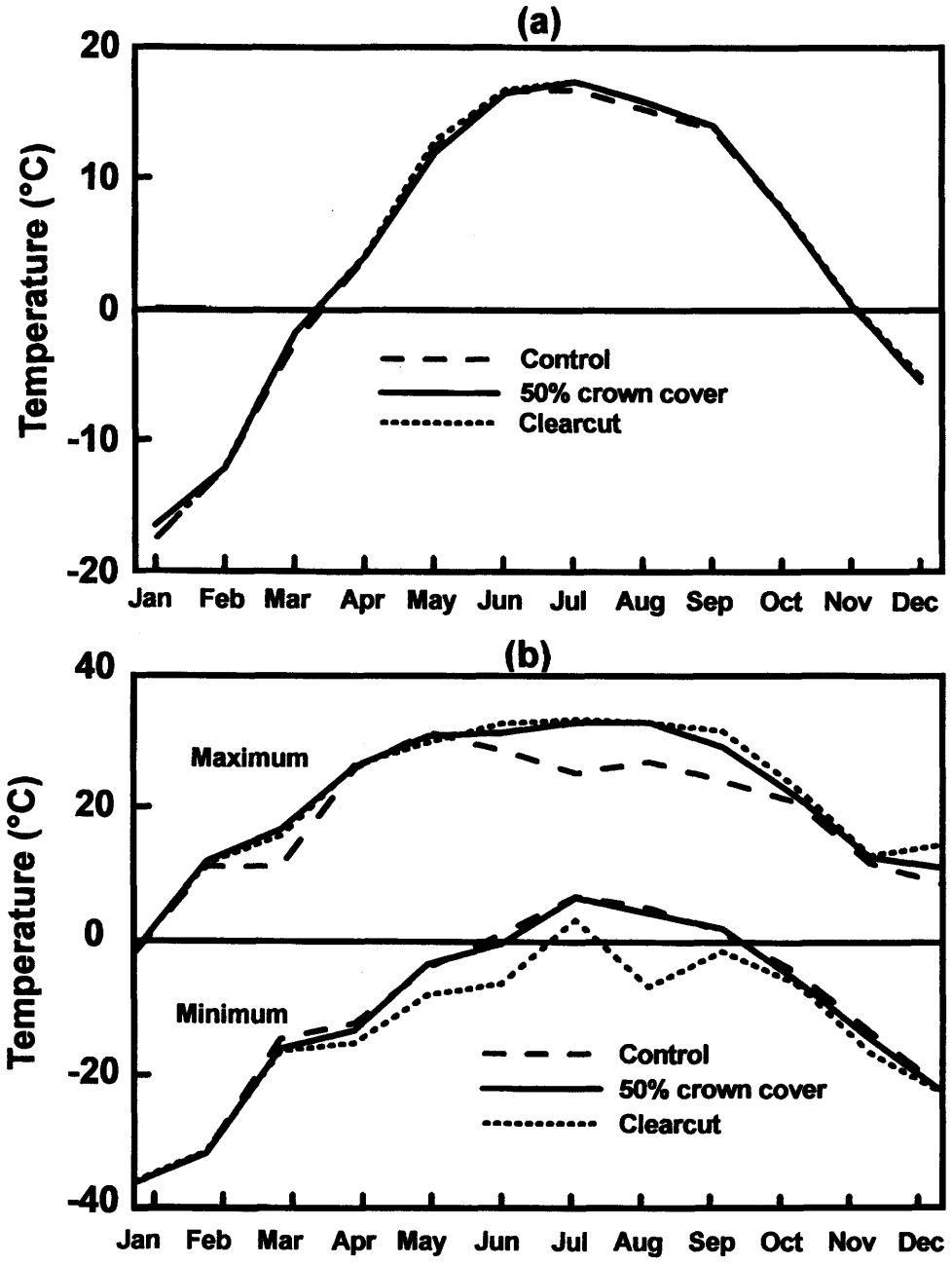

Figure 1.—Average (a) and maximum and minimum (b) monthly temperatures for the control, 50 percent crown cover, and clearcut treatments in the partial cutting study 1.0 m above the ground, 1994.

and the response of the biotic community—flora and fauna—to the changes in microclimate resulting from canopy gaps of different sizes. Gap sizes being studied are: 5.5, 10, 20, 30, and 45-m in diameter, and a control.

Temperatures are recorded from 13 locations within each of three of the gap sizes (control, 20 m, and 45 m diameter gaps). These are located at the center, midway between center and canopy edge, the canopy edge, and 5 m beyond the edge and beneath the canopy along an east-west and north-south transect of each gap. At each sampling point, temperatures are recorded at 1.0 and 0.1 m aboveground and at 0.03 and 0.15 m belowground.

RESULTS

Average Monthly Temperature

Average daily or monthly temperatures differed among treatments in the partial cut study (Figure 1). However differences were distinct in the temperature range (maximum to minimum variation) in both studies (Figures 1 and 2). This variation was more evident during the growing season than during the dormant season. Temperatures were cooler at night and warmer during the day in the clearcut and 45-m gap treatments than in the control. Average maximum temperatures were warmer and average minimum

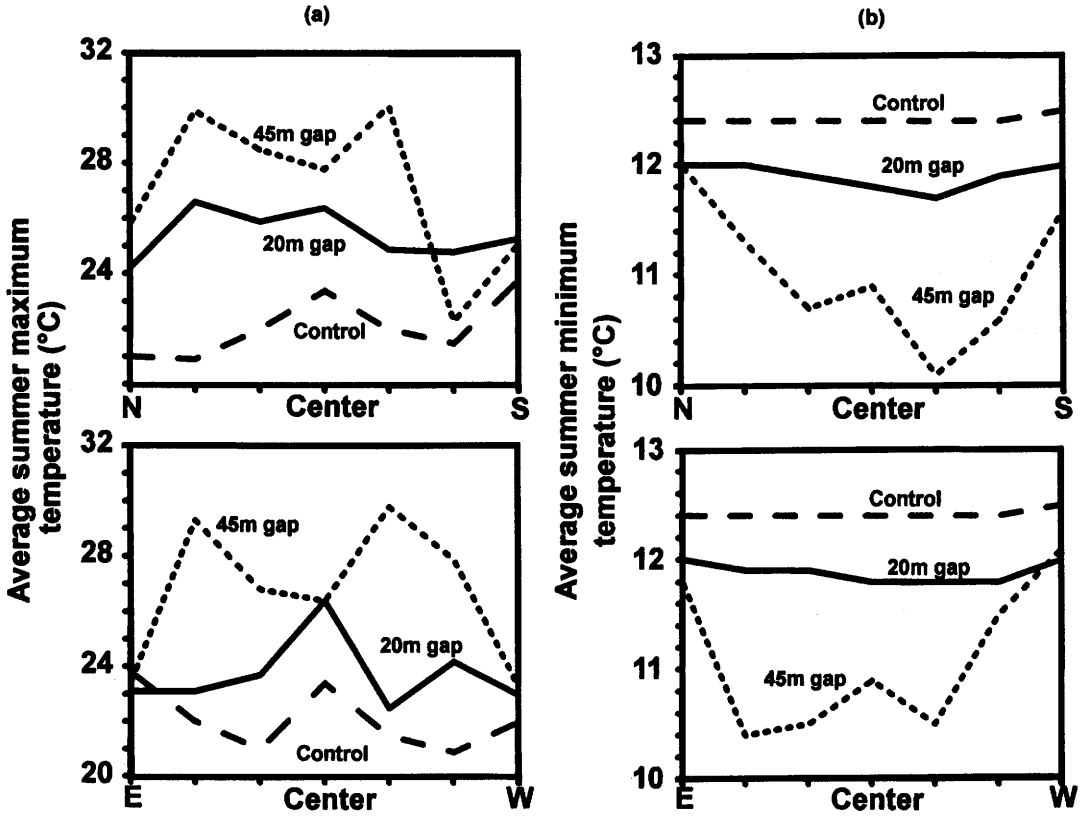

Figure 2.—Average summer maximum (a) and minimum (b) temperatures for the control, 20-m gap, and 45-m gap treatments in the canopy gap study 0.1 m above the ground, 1995.

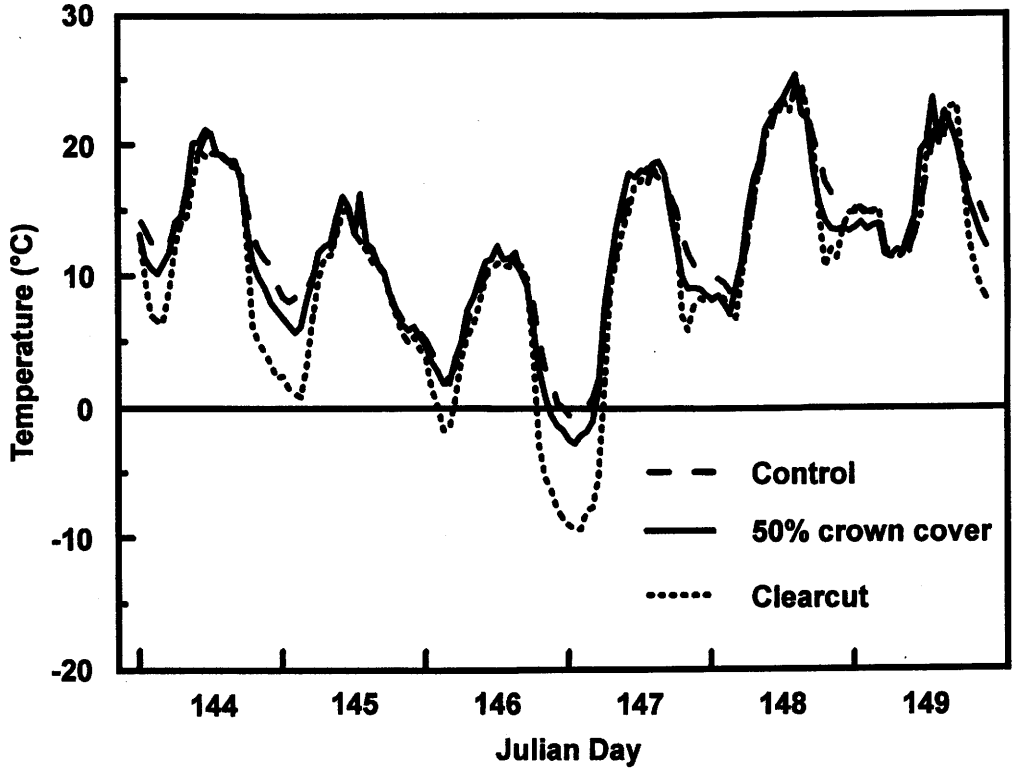

Figure 3.—Minimum temperatures in the partial cutting study for the control, 50 percent crown cover, and clearcut treatments, May 26-27, 1994.

temperatures were cooler in the center of the gaps than in the control and under the canopy beyond the edge of the gaps.

Temperature Profiles

Temperature differences among treatments at each measurement height at the center position of the canopy gap study did not vary during the winter (Table 1). However, temperature differences did occur among treatments at each measurement height during the summer, warmer in the 45-m gap than in the control. During the winter, temperatures are warmer in the soil and at 0.1 m above the soil surface than at 1.0 m above because of snow cover. Temperature patterns reversed during the summer: cooler in the soil and the warmest temperatures 0.1 m above the soil surface. Similar trends were found in the partial cutting study.

Table 1.—Profiles of average maximum temperatures (° C) for the center of the control and 45-m gap in January and July, 1996

Measurement location (m)	January		July	
	Control	45-m gap	Control	45-m gap
1.00	-8.0	-7.7	23.7	27.5
0.10	-1.8	-1.4	24.2	30.5
-0.03	0.4	0.4	16.6	23.0
-0.15	1.3	1.0	15.8	20.1

Temperature Extremes

Frost. Late spring frosts occur frequently in northern Wisconsin. Some are severe enough to kill newly expanding foliage and may kill the plant. Examples of several frost events are shown in Figures 3 and 4. Frosts were most severe in the clearcut treatment of the partial cutting study and in and around the center of the 45-m gap in the canopy gap study. Temperatures below freezing also occurred in the intermediate treatments but were not as low. Temperatures in the clearcut fell to nearly -10°C the morning of May 27, 1994. New growth on oak seedlings and saplings was killed. The seedlings and saplings did recover, but growth for the season was less in the clearcuts than in the control and 50 percent crown cover treatments.

High Temperatures. Extreme high temperatures not only can kill trees but also can dry the upper soil due to high evaporation from the soil surface limiting moisture to newly germinating seedlings. High temperatures are most critical at or near the soil surface. In the canopy gap study, the highest temperatures occurred in the center of the 45-m gap and clearcut

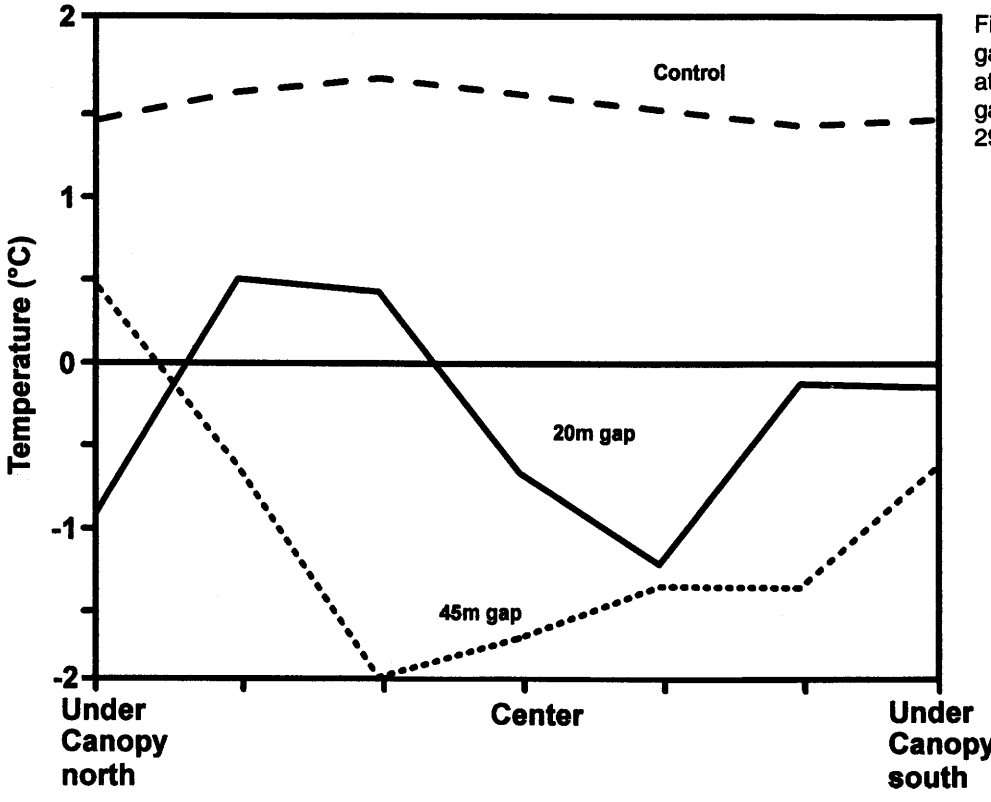

Figure 4.—Frost event in the canopy gap study 0.1 m above the ground at the center of the control, 20-m gap, and 45-m gap treatments, May 29, 1995.

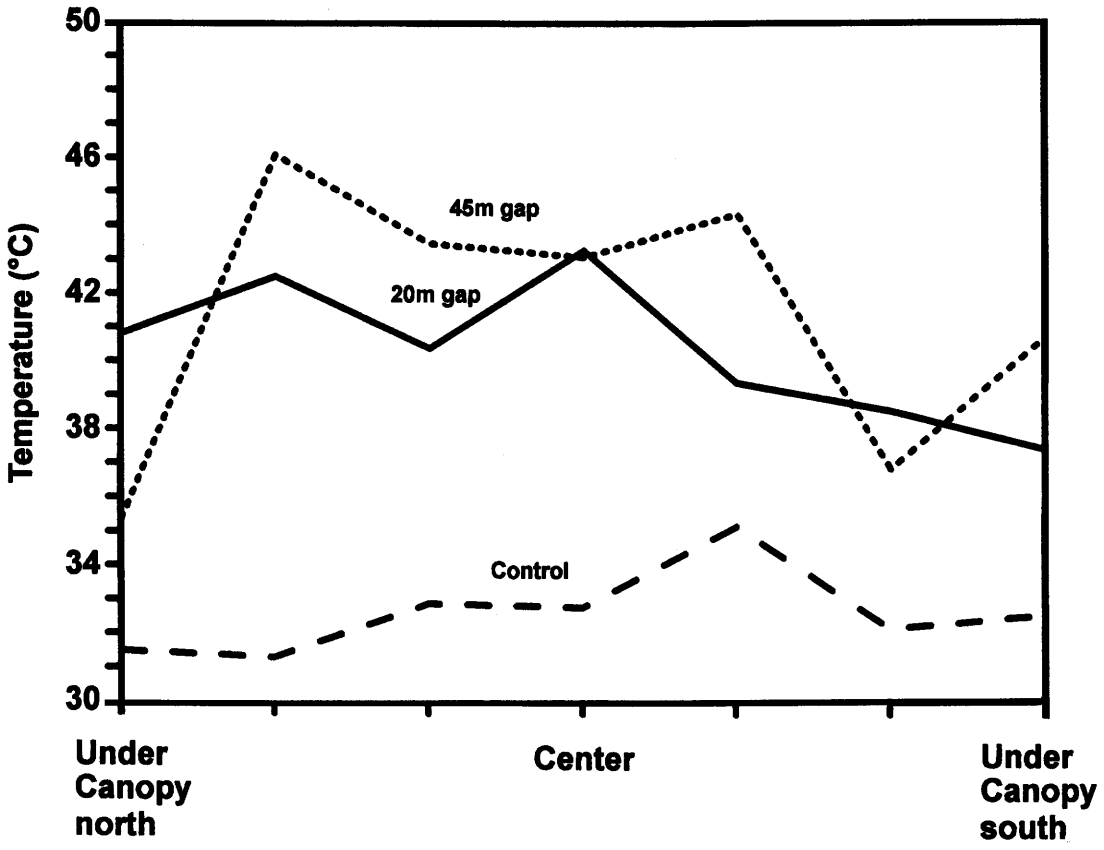

Figure 5.—Extreme high temperature events in the canopy gap study 0.1 m above the ground at the center of the control, 20-m gap, and 45-m gap treatments, June 18, 1995.

treatments (Figure 5). On June 18, 1995, temperatures rose to 46°C 0.1 m above the soil surface on the north side of the 45-m gap. Sustained temperatures at this level not only stop growth but also may kill small seedlings. Similar temperatures were recorded in the clearcut treatment of the partial cutting study on the same day at 0.1 m above the soil surface.

SUMMARY

Silvicultural treatments certainly influence the microclimate near the ground. Cutting increases the range of maximum and minimum temperatures. Temperatures near the soil surface can reach lethal levels (both cold and hot) in larger openings. We need an understanding of the relationships between the environment and plant responses resulting from different silvicultural practices. Past monitoring of silvicultural practices has usually been of vegetation and usually tree species. Today we need to adapt old silvicultural practices to fulfill timber management objectives as well as those for wildlife, biodiversity, aesthetic, and other management objectives. To predict vegetation responses and to learn how to develop desired plant composition, monitoring of more than vegetation is required. By monitoring the microenviroment along with vegetation responses to different silvicultural practices, we can learn how to grow specific plants or plant communities by adapting the current silvicultural guides.

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Communicating the Role of Science in Managing Giant Sequoia Groves[1]

Douglas D. Piirto, Robert R. Rogers, and Mary Chislock Bethke[2]

Abstract.—Management of giant sequoia groves has been and continues to be a hotly debated issue. The debate has reached Congress, with all parties seeking resolution as to what constitutes an ecologically and publicly acceptable management approach. Determining the correct management approach and communicating that approach to the general public is the crux of the problem. Emerging concepts and principles of forest ecosystem management may provide a mechanism to seek resolution of these management problems related to giant sequoia.

The Memorandum of Understanding between the members of the recently formed Giant Sequoia Ecology Cooperative provided the impetus for the development of this first working paper, which attempts to: 1) describe the historical events that led to much of the controversy surrounding management of giant sequoia groves; and 2) propose three management goals to guide development of best management practices for giant sequoia groves.

INTRODUCTION

The giant sequoia (*Sequoia gigantea* [Lindl.] Decne.) is botanically related to the coast redwood of California, baldcypress (*Taxodium distichum* [L.] Rich) of the southeastern United States, and dawn redwood (*Metasequoia glyptostroboides)* of China. Known as Sierra redwood or giant sequoia, it is noted worldwide for its great longevity, enormous size, awe inspiring beauty, ruggedness, and decay-resistant wood properties. Individual giant sequoia trees are among the largest and oldest living organisms in the world.

Giant sequoias are found in approximately 75 scattered grove locations, occupying 36,000 acres of forest within a narrow 260-mile long belt in the Sierra Nevada mountains of California. At present, more than 90 percent of all grove acreage is in public ownership. The National Forest system, primarily the Sequoia National Forest, manages all or part of 41 groves and about 50 percent of the total grove area. The National Park system (i.e., Sequoia, Kings Canyon, and Yosemite National Parks) include all or part of 29 groves and 30 percent of the total grove area. Other public ownerships, including Mountain Home State Forest, Calaveras Big Trees State Park, the University of California, Bureau of Land Management, and Tulare County manage 10 percent of the total grove area. The remaining area (i.e., approximately 10 percent) of giant sequoia is privately held.

The tree has been surrounded by controversy from its discovery. Dr. Albert Kellogg, the first to possess specimens of giant sequoia in 1852, hesitated to apply the new genus name *Washingtonia* sp. to giant sequoia. This delay to act by Kellogg enabled an English botanist, John Lindley, to be the first to formally propose a new name for giant sequoia, *Wellingtonia* after the Duke of Wellington. This naming of giant sequoia by the English after a noted Englishman led to a cross fire of American controversy that lasted for decades (Ornduff 1994).

The controversy over naming giant sequoia, although no small matter, pales in comparison to the firestorm of controversies that have since resulted from management activities in giant sequoia groves. Initial reservation of the majority of giant sequoia groves in the late part of the 19th century and early part of the 20th century resulted from numerous complaints over the "exploitive logging" that was taking place in such locations as Converse Basin.

People continue to be concerned about the short- and long-term effects of increased recreational use, reintroduction of fire (e.g., high-intensity prescribed burns) and silvicultural management (e.g., removing a few to many of the competing tree species to enable germination, survival, and growth of giant sequoia trees). Numerous schools of thought or philosophies have been presented as to the "best" approach for giant sequoia management.

Many pure preservationists would advocate just allowing natural processes to occur. Others would argue that people have been part of the problem and people should be part of the solution favoring reintroduction of fire and/or thinning to bring giant sequoia groves back to some "natural" condition. Others would argue that protection of the objects during management activities (i.e., the magnificent old-growth giant sequoia trees as individual trees) must be a major part of our thinking as we move to "restore" ecological processes (Piirto 1992a, b; Piirto 1994). The controversy has turned vitriolic. Many law suits have resulted. Who's right?

Well-meaning people cannot seem to come to terms on an appropriate short- and long-term management strategy for giant sequoia groves. The authors have held numerous discussions with people of many different viewpoints. No matter how hard we try, there is significant consternation over the use of management tools, particularly silvicultural manipulation such as logging. What is wrong with this picture? All parties have a deep and abiding love for giant sequoia, yet there is significant "mistrust" between them.

[1]An abbreviated version of this paper was presented at the National Silviculture Workshop on May 20, 1997 in Warren, PA.

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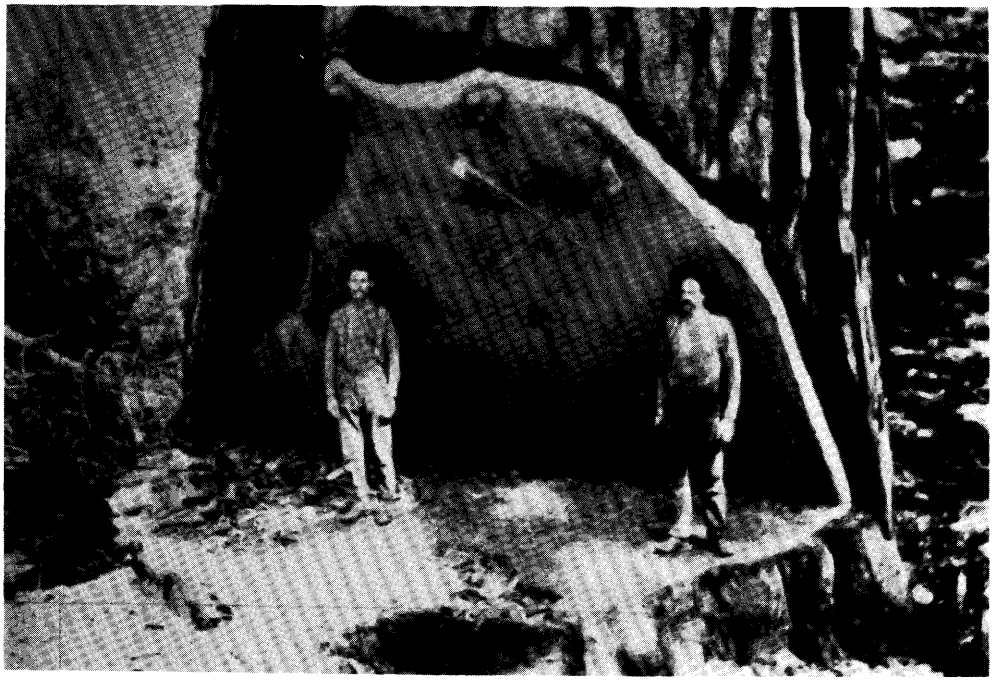

Figure 1.—This Mark Twain tree stood on privately owned land when it was cut in 1891 for museum exhibition purposes. The logged over area now known as the Big Stump grove is under the federal jurisdiction and protection of Sequoia National Forest. (Stauffer Publishing Co. photo).

The arguments surrounding giant sequoia management are a classic case of the failure to communicate. Terms, concepts, and principles have not been accurately defined, particularly with reference to silviculture and ecosystem management. Expected outcomes (i.e., desired condition) are often poorly described and difficult to visualize in relation to the natural range of conditions. A process for enabling communication, collaboration, and resolution of giant sequoia issues is sorely needed.

Finding the best way to manage a giant sequoia grove is a goal that all of us can agree to. The next step is to implement a process that will enable us to achieve this goal on a grove-by-grove basis. This paper attempts to discuss some of the important considerations to achieve "best management of giant sequoia groves." The objectives of this paper are to:

1. Describe the historical events that have led to much of the controversy surrounding management of Forest Service giant sequoia groves.
2. Propose three management goals for achieving best management of the giant sequoia groves.

HISTORICAL PERSPECTIVES

Giant sequoia trees have commanded a high level of respect and regard for a long time, as summarized by President George Bush in 1992: "For centuries, groves of giant sequoia have stimulated the interest and wonder of those who behold them. The giant sequoia inspires emotion like no other and has mystically entered the hearts of humanity everywhere." A complete understanding of the historical record is needed in make informed and correct decisions for the management of giant sequoia groves. A brief account of this human association with the giant sequoia/mixed conifer ecosystem is provided in the sections that follow.

Prehistory

About 20 million years ago, trees closely related to the giant sequoia grew in a large area of the western United States (Harvey 1985). Over geologic time, these ancestral trees disappeared. Their descendants, the modern giant sequoia, are found in about 75 scattered locations within a narrow 260-mile long belt at an elevation between 4,500 and 7,500 feet in the Sierra Nevada (Harvey 1985; Weatherspoon 1986).

Scientists currently conclude that human association with the giant sequoia ecosystems spans some 10,000 to 12,000 years. Archaeological evidence of human use and habitation of giant sequoia groves has been found (Hull 1989).

Uncontrolled Exploitation (1850-1890)

The giant sequoia of California were evidently observed by the Walker party in 1833, and probably before that by Spanish explorers. However, it wasn't until after the rediscovery by A.T. Dowd in 1852 that there was any public attention to the species.

The first phase of economic exploitation started almost immediately after Dowd's discovery. In 1853, a large giant sequoia in the Calaveras grove was felled for exhibition purposes. The Mark Twain tree was felled for exhibition purposes in 1890 (Figs. 1-2). The "big stump" that was left behind became the focal point for naming the area we currently know as the Big Stump grove. The last exhibition

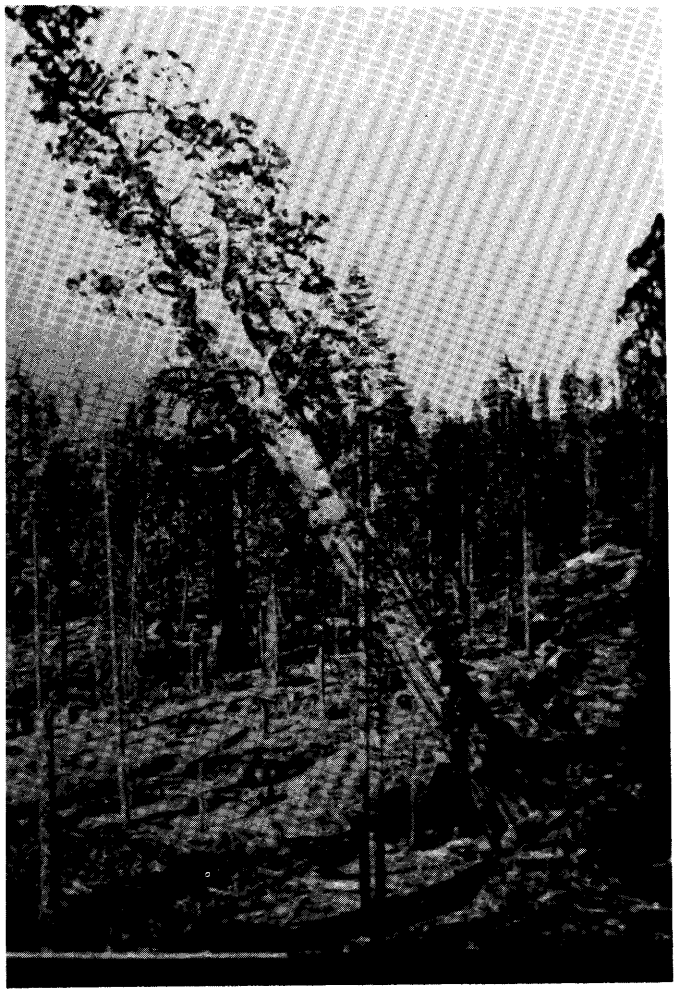

Figure 2.—The Mark Twain tree as it falls to the ground (Stauffer Publishing Co. photo).

tree probably was cut in 1893 for the Chicago World's Fair. Commercial logging of the species began to gain momentum in the 1860's (Johnston 1996).

Noncommodity values were recognized very early, probably as a direct result of commercial exploitation. Newspaper editorials as early as 1853 exposed the moral issue involved in cutting the big trees. In 1864, the federal government deeded Mariposa grove to the State of California "...for public use, resort, and recreation...." Elsewhere however, logging of the big trees for wood products had reached such a rate that in 1873, the California Legislature passed a law making it a misdemeanor to "...willfully cut down or strip of its bark any tree sixteen feet in diameter...."

State law was largely ignored; by the 1880's, much public land containing giant sequoia groves had been acquired by large lumber companies. Most of this land was south of the Kings River in Fresno County, now within the Sequoia National Forest. In 1890, a flume was completed that heralded a truly colossal event in the history of human relationships with the giant sequoias—the logging of the Converse Basin grove and its environs by the Kings River Lumber Company (Johnston 1996).

Pinchot and Muir Think Alike (1890-1930)

On the issue of giant sequoia logging John Muir (Fig. 3) and Gifford Pinchot (Fig. 4) were very much in agreement as is evidenced by the following statements:

"...timber was magnificent. But who shall describe the Sequoias? Their beauty is far more wonderful that their size." (Pinchot 1947).

"The Big Tree...is Nature's forest masterpiece, and, so far as I know, the greatest of all living things." (John Muir).

"So with John Muir and Hart Merriam, Head of the Biological Survey, I made a memorable trip to the Calaveras Grove...Never were two more delightful talkers that Muir and Merrian...I could have sat in the front seat of our wagon and listened to them for weeks..." (Pinchot 1947).

"...I ran into the gigantic and gigantically wasteful lumbering of the great Sequoias...I resented then, and I still resent, the practice of making vine stakes hardly bigger than walking sticks out of these greatest of living things." (Pinchot 1947).

"In this glorious forest the mill was busy, forming a sore, sad centre of destruction...And as the timber is very brash...half or even three fourths of the timber was wasted." (John Muir).

Adverse public reaction to the logging was picked up and amplified by George Stewart, editor of the Visalia Weekly Delta newspaper. His campaign led to the establishment of Sequoia and General Grant National Parks in 1890. Stewart was also instrumental in creating the concept of "forest reserves" which later provided the land from which many of our National Forests were created.

Grove Protection (1930-1960)

Logging and lumbering of giant sequoia groves like Converse Basin was largely completed because of economic conditions by 1930. Most privately held lands containing giant sequoias, including those that had been cutover, passed into either state or federal ownership between 1926 and 1960. This conversion of land ownership from the private sector to the government sector was thought to be a benevolent action leaving few threats to the giant sequoia groves.

Grove Protection Revisited (1960-1980)

By the 1960's, foresters and scientists in all the agencies responsible for giant sequoia management, began to realize that successful fire suppression during the past 50 years or so was allowing dangerous amounts of fuel to build up in the groves. Also, the lack of canopy openings and bare soil as

Figure 3.—John Muir, President Teddy Roosevelt, and a group of people at the base of a giant sequoia in Yosemite National Park in 1903 (Harcourt Brace Co. photo).

created under natural fire regimes was inhibiting reproduction of the species. Instead, white fir and incense-cedar were becoming established in great numbers (Fig. 5). We now understand that grove protection by aggressive fire suppression alone was insufficient. Fuel reduction and control of vegetation structure are also necessary for long-term well being of the giant sequoia groves. The National Park Service began some of the first major experiments with prescribed burning as a means to overcome the problems that followed fire suppression. Harold Biswell at the University of California at Berkeley was a pioneer of this early fire management research.

Forest Service Management Begins (1980-1990)

By 1980, fuel-reducing prescribed fires were being programmed routinely in the groves of Sequoia and Kings Canyon National Parks, and at a much smaller scale in Yosemite National Park. The National Park Service received much criticism for an early prescribed burn conducted in the Redwood Mountain grove (Fig. 6). In 1985, the program was suspended because of accumulating criticism of smoke in the air, occasional hot spots that singed crowns and even killed some larger fir and pine trees, and most of all, char on large giant sequoia trees. This controversy arose in part because many of the critics focused attention on individual specimen trees, whereas the National park Service focused more broadly on the ecosystem in which these trees lived...different perspectives within the same social environment led to

Figure 4.—Pinchot and Roosevelt conferring during an Inland Waterways Commission trip on the Mississippi River in October 1907 (Harcourt Brace Publishing Co. photo).

Figure 5.—High understory density of various tree species poses a significant fire hazard in giant sequoia groves. These high density levels have largely occurred because of fire suppression activities.

the conflict. A considerable amount of controversy still remains as to the "appropriate" way to reintroduce fire in giant sequoia groves and surrounding areas.

Wary of the sensitive nature of giant sequoia groves, the Forest Service was much slower to begin active management. In 1975, the Sequoia National Forest made a modest attempt at prescribed burning in the Bearskin grove. Fuel loading was reduced and numerous giant sequoia seeds germinated in the burned area. However, most of these new seedlings died, presumably because of a lack of sufficient canopy opening and exposure to mineral soil. It was concluded that the fire wasn't "hot enough" to fully accomplish all of the fuel objectives; and if it had been, there would have been dead but unconsumed trees left on the site to produce more fuel in the future. This conclusion led Forest Service managers in 1983 to prescribe a "seedtree" regeneration harvest for approximately 15 acres of the Bearskin grove area (Fig. 7) to accomplish both fuel reduction and giant sequoia seedling establishment objectives (Fig. 8). The action in Bearskin grove set a precedent for other timber sales in other groves with objectives expanded to include timber production as well.

Even though the Forest Service complied with public involvement requirements of the National Environmental Policy Act (i.e., NEPA), it is evident that a consensus of public approval was lacking. When the logging was independently discovered by some who tended to be critical of Forest Service anyway, the sense of betrayal

Figure 6.—The results of a National Park Service prescribed burn in Redwood Mountain.

Figure 7.—Silvicultural treatments were completed on 15 acres of the Bearskin grove, Hume Lake Ranger District, Sequoia National Forest.

Figure 8.—Treating giant sequoia groves via selective cutting practices followed by prescribed burning or some sort of site preparation treatment is needed to create desired microsite conditions favorable for giant sequoia seedling/sapling survival and growth.

sent shock waves of dismay through the environmental community. Realizing the agency had gone too far too fast, The Sequoia National Forest ceased timber harvest within giant sequoia groves in 1986.

Since the late 1980's, and continuing to the present, articles about forest management featuring giant sequoias have appeared in newspapers, magazines, and on television. Articles like the Sacramento Bee's eight-part series titled "Sierras Under Siege" and other articles in Audubon, National Geographic, Sunset, Sports Illustrated and documentaries on CNN and the MacNeil-Lehrer program have caused increased visibility to what is occurring or not occurring in giant sequoia groves. Many letters have and continue to be received by various Forest Service offices from citizens concerned about the effective management of giant sequoia groves.

The 1988 Forest Plan for the Sequoia National Forest as mandated by the National Forest Management Act of 1976

and other laws did not satisfy the critics of Forest Service giant sequoia and resource management policies.

The Mediated Settlement (1990-2000)

In 1990, a Mediated Settlement Agreement (MSA) was reached on 25 forest planning issues for the Sequoia National Forest. More pages of this MSA document are devoted to giant sequoias that even timber sale quantity or watershed effects, both of which are consider "mega" issues. The basic agreement is to remove the groves from regulated timber harvest and "to protect, preserve, and restore the groves for the benefit and enjoyment of present and future generations."

But the public clamor about giant sequoia management on the Sequoia National Forest did not stop. In 1991, Congressmen Lehman and Dooley convened a hearing on that specific issue. Because of administrative agreements reached through mediation, unsettled issues focused mostly on questions about the state of ecological knowledge. It was at this hearing that the senior author of this paper presented a witness statement (Piirto 1991) outlining a number of lessons learned from past management practices and listing a number of recommendations. The lessons learned are as follows (Piirto 1991):

1. There continues to be significant interest in the giant sequoia resource as there well should be. Yet this interest and concern is not supported by adequate funding to do research and carry out management in and orderly and planned manner.
2. Organizations and agencies involved with giant sequoia management have varied opinions as to what is the most appropriate course of action to follow.
3. Very little research has been done on giant sequoia particularly from the standpoint of comparing and evaluating management approaches.
4. Significant site disturbance is needed to obtain giant sequoia seedling establishment and survival. Mineral soil conditions favor seedling establishment and canopy openings facilitate growth and survival of established seedlings.
5. Thrifty young-growth stands of giant sequoia are not widespread within its native range.
6. Fire suppression over the past 90 years has resulted in significant stand density increases of associated tree species found in giant sequoia groves. It is possible that these changes in stand density are also influencing pathogen and insect relationships in the grove areas.
7. Both prescribed burning and silvicultural manipulation of giant sequoia groves have positive and negative effects which are not fully understood. For example, researchers have measured lethal temperatures at significant depths beneath the bark of old-growth giant sequoia trees during prescribed burning operations.
8. Custodial protection without some form of prescribed burning and/or silvicultural manipulation is probably not in the best interest for perpetuating the species.
9. Giant sequoia trees are subject to the same natural forces and man-caused influences as other tree species. Specimen giant sequoia trees have fallen within the boundaries of National Parks, State Parks, State Forests, National Forests and on private lands. Various factors are involved. And in some cases human activities have probably contributed to premature failure in all of these governmentally protected and managed areas. It is not known whether or not the present rate of old-growth giant sequoia tree failures is higher than historic patterns.
10. Both prescribed burning and silvicultural manipulation of giant sequoia groves have received adverse public criticism. It seems that no one agency is doing a perfect job of giant sequoia management. However, Mountain Home State Forest might come closest if we were to judge performance on the amount of public criticism expressed and publicity received. But the jury is still out as to what management approaches are most effective for perpetuation of the ecosystem and the giant sequoia species.

Based on these lessons learned, the following recommendations were made (Piirto 1991):

1. Management by necessity must involve more than custodial protection. And it can't simply focus on changing jurisdictional authorities. Management must be continuous as the ecosystems within which giant sequoia occurs are dynamic.
2. Do not alter present agency jurisdictions of giant sequoia groves. There is no evidence to suggest that one agency is doing a better job than another. The perpetuation of the species may be best served by a variety of management approaches.
3. Require that grove boundaries and permitted management activities be clearly identified for all giant sequoia groves following applicable NEPA procedures. This is largely what is stipulated in the 1990 Sequoia National Forest mediated settlement of the Land Management Plan. This requirement should be extended to all giant sequoia grove areas under federal management.
4. Provide funding and mechanisms to enable research symposiums and short courses on giant sequoia to occur on a timely and scheduled basis.
5. Establish a giant sequoia research center which would clearly identify research priorities. This research center would serve to insure that research is carried out in a timely manner. I would suggest that this center be housed within the USDA Forest Service's PSW Research Station or in a university where a spectrum of research can be accomplished irrespective of management direction.
6. Provide adequate federal funding to ensure appropriate and sustained management of the giant sequoia ecosystem. Identify giant sequoia management and research as specific line items in the federal budget.
7. Establish giant sequoia program managers in those federal agencies (e.g., National Park Service, Forest Service, Bureau of Land Management) which have a significant giant sequoia land base.

Regional Forester Ron Stewart accepted these recommendations and those made by other witnesses at the hearing. He directed other National Forests in California (primarily the Tahoe and Sierra National Forests) to adopt

the mediated settlement agreements on giant sequoia management and called for a symposium which would bring together scientists and others interested in giant sequoias.

Further federal action came in July 1992 in the form of a proclamation made by President Bush. The proclamation removed National Forest groves from the timber production land base, affirmed the terms of the Mediated Settlement, and directed that the groves "shall be managed, protected, and restored by the Secretary of Agriculture...to assure the perpetuation of the groves for the benefit and enjoyment of present and future generations." The Forest Service finally had coordinated management direction at the local, regional, and national levels.

Since 1992 there has been general agreement on how giant sequoia groves should be treated on National Forests; yet public apprehension remains. This is evidenced by the Sierra Nevada Ecosystem Project (SNEP) charge to examine the Mediated Settlement Agreement and make recommendation for scientifically based mapping and management of the groves (University of California 1996). New legislation is still being proposed such as the Sequoia Ecosystem and Recreation Act of 1996 (HR 3873) which proposed "...to protect and preserve remaining Giant Sequoia ecosystems." The fact that committees are being formed and legislation is being proposed demonstrates that issues still exist. Additional issues will likely develop as management actions are enacted in response to the following statement made in the SNEP report (University of California 1996): "There is evidence to suggest that inaction is currently the most significant threat to giant sequoias, the groves and their ecosystems."

History Lessons

What lessons can we now say we have learned from this long human association with giant sequoia groves:

1. Native Americans, prominent American conservationists (e.g., John Muir, Gifford Pinchot) and people from all walks of life view giant sequoia groves as special places requiring careful management and stewardship.
2. A high degree of controversy has and continues to surround "exploitive logging" of giant sequoia groves for purely commercial reasons.
3. Governmental grove protection and aggressive fire suppression were not enough. Fuel reduction and control of vegetation structure are also necessary for long-term well being of the giant sequoia groves.
4. The results of management actions are time dependent. Judging the effectiveness of a management action shortly after it has occurred can lead to erroneous conclusions. A need exists for coordinated management and research activities to demonstrate both the short- and long-term effectiveness of management actions.
5. There has been significant public interest in giant sequoia for the last 147 years. Concerned publics and land managers in recent times have not effectively communicated with one another particularly with reference to identifying goals, establishing management plans, and visualizing the change in giant sequoia groves that can occur whether or not management plans are put into motion.
6. Most people agree that the reintroduction of fire and even thinning are necessary management actions in giant sequoia groves. The controversy seems to be focus on what constitutes an appropriate prescription for these management activities. How is success measured?
7. Concerned publics will enter the legislative arena to seek resolution of contentious controversies surrounding management of giant sequoia groves.
8. Federal officials (i.e., Lynn Sprague, current Regional Forester; Ron Stewart, prior Regional Forester; Phil Bayles, prior Forest Supervisor of the Sequoia National Forest; Sandra Key, prior Forest Supervisor of Sequoia National Forest; Art Gaffrey, current Forest Supervisor of Sequoia National Forest; and Jim Boynton, current Forest Supervisor of the Sierra National Forest) have been responsive and in many cases proactive to the recommendations made at the 1991 Congressional hearing in Visalia. The following management actions have occurred since the 1991 hearing:
    a. A symposium titled "Giant Sequoias: Their Place in the Ecosystem and Society" was held in 1992.
    b. Two positions dedicated to management and coordination of giant sequoia research have been created on the Sequoia National Forest. Robert Rogers holds the position of Giant Sequoia Specialist and Mary Chislocke Bethke holds the position of Giant Sequoia Program Manager. Similar positions exist in other federal and state agencies.
    c. A Giant Sequoia Ecology Cooperative has been formed.
    d. Grove boundaries have been clearly identified and mapped for most if not all National Forest giant sequoia groves.
    e. Federal funding is being provided.
    f. A Giant Sequoia Leadership Conference was held in Sacramento in January 1997.
    g. Many other significant actions and activities have occurred that are too numerous to list here.
9. A new vision has emerged as a result of the effective collaboration that was started with the mediated settlement, the 1991 congressional hearing, and the 1992 Giant Sequoia Symposium. However, issues and controversy over giant sequoia management still exist.
10. Management inaction was noted in the SNEP report as the most significant threat to giant sequoias.
11. Past public attitudes toward giant sequoia have not always been science based. Understanding what the public wants with reference to giant sequoia management will be important as future management plans for giant sequoia groves are developed. It will be important to properly frame the issues surrounding giant sequoia management.

One thing becomes impeccably clear after reviewing this historical record, the problems and issues that have surrounded giant sequoia will not be resolved with the same

level of consciousness that created them. Hopefully, the richness of the process to reach a higher level of consciousness to resolve these giant sequoia problems will be as rewarding as the end result.

MANAGEMENT GOALS FOR GIANT SEQUOIA GROVES

Determining the right goals for management of giant sequoia groves is the most difficult task managers face. The following goals based on the best available science and public collaboration (i.e., Mediated Settlement Agreement on the Sequoia National Forest) to date are listed to facilitate current and future discussion on the management tactics and strategies necessary to achieve "best management of giant sequoia groves":

1. Protect naturally occurring groves, and historical and biological artifacts within them, from events such as excessive logging activities, excessively hot fires, and inappropriate human uses that are contrary to, or disruptive of, natural ecological processes.
2. Preserve the groves in a natural state by allowing ecological processes, or equivalents thereof, to maintain the dynamics of forest structure and function.
3. Restore the groves to their natural state where contemporary human activities have interfered with the natural processes—especially fire and hydrology.

It is critical for the Forest Service and the public at large seek agreement to these goals to protect, preserve, and restore giant sequoia groves. Successful completion of the collaborative demonstration projects beginning on the Sequoia and Sierra National Forests depend on it. The next step is to put the accumulated knowledge of science and management experience to work in such a way that satisfies the public demand to protect, preserve, and restore the giant sequoia groves under federal jurisdiction.

CONCLUSION

Attempting to resolve the vitriolic conflict over giant sequoia management will not be an easy task. It can be interpreted from the history lessons of our prior association with giant sequoia that a new process for arriving at best management decisions is needed. Perhaps ecosystem management will be that process to achieve a higher level of consciousness. Information and clear communication, however, will be needed in order to effectively implement ecosystem management.

A large amount of "quality" research work has occurred since the 1992 Giant Sequoia Symposium as an information base for the ecosystem management process (Aune 1994). The 1992 Symposium has led to many positive outcomes particularly in the scientific arena (i.e., numerous studies have been completed since then). The findings of these studies will be useful to analyses involving giant sequoia groves. A review of some of this current research is presented in Piirto (1996).

Expanding populations, increased and often conflicting demands for public lands, the expanding urban interface, increasing recreational use and associated impacts, increasing risk of damaging fires, reduced availability of federal funds, inefficient technology transfer, and failure to resolve conflicts are just a few of the many reasons why a new forest ecosystem management decision process is needed. It will be essential as this process is implemented that close and structured cooperation with agency personnel (e.g., National Park Service, California Department of Forestry, Bureau of Land Management, Forest Service, California State Parks), environmental organizations (e.g., Sierra Club, Save-the-Redwoods League), the forest products industry, and concerned citizens continue to develop. An improved cooperative spirit seems to be emerging as evidenced by the positive outcome of the 1992 Symposium and the recent formation of the Giant Sequoia Ecology Cooperative.

Working together, we can make a difference in finding the "right ecosystem management solutions" for giant sequoia groves. But we should also remember what Ticknor (1993) stated:

> "Sooner or later, our management decision process will be informed by reliable answers to these questions, but the answers, contrary to our wishes, will seldom be couched in terms of right or wrong, yes or no. They require the election of alternatives, the exercise of judgment, and the action of choosing."

And we should all understand what Theodore Roosevelt was trying to tell us in his address titled "Citizenship in the Republic" at the Sorbonne in Paris on April 23, 1910:

> "It is not the critic who counts; not the man [human] who points out how the strong man [human] stumbles, or where the doer of deeds could have done better. The credit belongs to the man [human] who is actually in the arena, whose face is marred by dust and sweat and blood; who strives valiantly; who errs, and comes short again and again, because there is no effort without error and shortcomings."

The practice of silviculture is at a crossroads today. Will Silviculturists embrace the emerging principles and concepts of ecosystem management and put them into practice? Ecosystem management is about breaking down barriers. It could become the process via which we rise to a new level of awareness in managing giant sequoia groves. It seems that silviculturists and giant sequoia may have something in common: a relic of the past or an icon to the future (Fig. 9). The choice is ours to make.

ACKNOWLEDGMENT

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Figure 9.—The General Grant Tree in Sequoia-Kings Canyon National Park. A relic of the past or an icon to the future, the choice is ours to make.

forests. The impetus to develop this first "working paper" came from direction provided in the Memorandum of Understanding which formed the cooperative. This paper is dedicated to Rueben and Martha Piirto.

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Communicating the Role of Genetics in Management

Mary F. Mahalovich[1]

Abstract.—Three current issues serve as examples to convey the role of genetics in management. (1) Consequences of silvicultural systems on the genetic resource of tree species are limited to one generation of study and isozyme (qualitative) data. Results of simulated data for diameter (quantitative data) over several generations, illustrate the pitfalls of working towards balanced uneven-aged silvicultural systems in northern red oak, under natural regeneration constraints and existing management direction. (2) Comparisons of section boundaries within an ecological classification system and climatic zones (homoclines) as surrogates for managing genetic resources, are of limited utility in describing patterns of genetic variation for adaptive, growth, and disease resistance traits. (3) Reporting gains and seed yields from tree improvement programs in Forest Service decision documents is recommended as means of showing consequences of 'action vs. no action' for genetic resources, thereby placing genetics in a more active role in the Agency's next round of forest planning.

INTRODUCTION

An effective communication method for highlighting the role of genetics in ecosystem management is to relate genetic principles and tree improvement programs in the context of current events and issues driving land management practices. DeWald and Mahalovich (1997) and Mahalovich (1995) highlight the importance of improving forest health and conserving genetic diversity by the application of seed transfer guidelines and breeding for insect and disease resistance in tree improvement programs. This paper extends those considerations to (1) the consequences of managing species under natural regeneration constraints and uneven-aged silviculture, (2) the application of coarse-filters, e.g., ecological classification systems and homoclines in regulating seed movement and structuring tree improvement programs, and (3) infusing genetics in the Agency's next round of Forest Plan revisions.

Consequences of even- and uneven-aged silvicultural systems on genetic resources remains an open field of study. Research into the impacts of even-aged silvicultural systems has empirically shown little change in the genetic constitution of forest tree populations in one generation of shelterwood harvests in Douglas-fir (Neale 1985) or seed-tree harvests in Scots pine (Yazdani et al. 1985). The resiliency of the genetic structure has been presumed to be due to high within-stand and individual-tree heterozygosity (trees are relative new comers to domestication), maintenance of large effective population size after reduction in density of the parental population, and a high rate of outcrossing within shelterwoods (Neale 1985). These landmark studies however were based on isozyme data, which have shown no direct correlation among adaptive, growth, or insect and disease traits in forest tree populations (Mitton 1995, Savolainen and Kärkkäinen 1992).

CONSEQUENCES OF UNEVEN-AGED SILVICULTURE

Mahalovich (1993) designed a model (NATGEN) to overcome some of the limitations of previous even-aged studies in an attempt to address the longer term issues of uneven-aged silvicultural prescriptions, using a quantitatively inherited character. The first version of the northern red oak model allows the end user the opportunity to evaluate the consequences of various cutting levels on tree diameter for up to 10, 80-year rotations: (1) cutting from below, (2) cutting from above, and (3) a combination of cutting from above and below. Following harvest, the stand of 100 trees is naturally regenerated using the leave-trees as parents. The modeling scenario that focuses on diameter-limit cutting of trees 18 inches and above, results in the inability to achieve larger diameter trees after 5-7 rotations. Stated from a genetics perspective, once the heritability for diameter drops from 0.2 to below 0.1 and/or the desirable gene frequency drops from 0.5 to 0.01, the population of 100 trees is unable to recover without artificial regeneration, albeit genetically improved northern red oak.

The author was further challenged by Eastern Region silviculturists to evaluate mitigating factors, i.e., larger population size, variable cutting intervals, and advanced reproduction. For a population of 600 trees, cutting from above (18 inches or greater) results in fewer, larger diameter trees over time. This result is also mirrored by a decline in the genetic resource with the initial heritability for tree diameter falling below a value of 0.2 and desirable gene frequencies dropping below a value of 0.5. This model also shows that even if several 20-year cutting cycles are skipped, rotation ages are extended beyond 80 years, or advanced reproduction is chosen as the natural regeneration option, it is difficult to achieve 30-inch or greater, diameter trees in this population of 600 trees.

For the larger population size of 600, the concept of genetic diversity is evaluated by defining effective population size as the number of reproductively mature parents for both the seed tree and advanced reproduction, natural regeneration options. Effective population size described in this manner is over-simplified because it doesn't directly address the genetic constitution of parent trees, but is useful for end users with a limited background in genetics. When adequate numbers of parents are left for natural regeneration, further evaluation of their ability to meet the criteria for reproductive maturity (minimum of 10 inches in diameter and 80 years of age) can result in an effective population size of zero when diameter-limit cutting is practiced from above or when the target residual basal area drops below 80 square feet per acre.

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Table 1.—Hierarchical classification systems in ecosystem management: (a) ecologic and (b) genetic

(a) Ecological	Unit Size	(b) Genetic	Unit Size
Province	Multiple States	Genus	Varies by Species
Section	1,000s of Square Miles	Species	at All Levels
Subsection	10s to 100s of Square Miles	Race	
Landtype Association	100s to 1000s of Acres	Variety	
Ecological Land Type	10s to 100s of Acres	Provenance, Stand	
Ecological Land Type Phase	1s to 10s of Acres	Family	
Site	Up to about 1 Acre	Individual (Clone)	

Both versions of NATGEN begin to provide insights into the long-term consequences of practicing uneven-aged silviculture under natural regeneration constraints and pressures to meet high harvest levels. These preliminary results highlight the potential problems in managing the genetic resource of forest tree populations exposed to more than four generations of dysgenic selection practices. Modeling a population of northern red oak under these constraints limits the users ability to meet timber targets after six rotations and fails to meet desired future conditions for larger diameter trees, even for a species that readily lends itself to uneven-aged silvicultural prescriptions. Diameter-limit cutting and high-grading are expected to have negative consequences over the long-term for both pioneer and intermediate species managed under natural regeneration constraints.

LANDSCAPE ASSESSMENTS AND GENETIC RESOURCES

Land management practices have recently included stronger inter-agency collaboration and the development of landscape-level assessments for proposed, desired future conditions of federally-owned lands, e.g., the Interior Columbia Basin Ecosystem Management Project and the Southern Assessment. A primary planning and management product of these assessments is the development of ecological classification systems (ECS). Managing genetic resources using an ECS or other coarse filters for individual species, has a high potential for inappropriate management of genetic resources, if applied to seed transfer guidelines in reforestation programs or in the development of seed orchard and breeding populations. There are beneficial examples of using an ECS for managing threatened and endangered species when genetic data are lacking.

Ecological Classification System and Seed Transfer

An ecological classification system is hierarchical in nature as are patterns of genetic variation within individual species (Table 1). An ECS is based on soils, landform, climate, and potential natural vegetation. Only 10-20 percent of an ECS is based on biological factors. In contrast to these predominantly physical factors, forces that shape patterns of genetic variation over time are selection, drift, mutation, and migration. Very few species show patterns of genetic variation based on physical factors. Notable exceptions are patterns of variation based on soil type in Bishop pine (Millar 1989) and white spruce (Khalil 1985) and differences in wet and dry sites with Engelmann spruce (Mitton et al. 1989). Presently, there is no information supporting patterns of genetic variation based on habitat type in western Oregon (Campbell and Franklin 1981) nor in Inland Northwest conifers, as long as elevation is included in the models for adaptive characters (Rehfeldt 1974a, 1974b). This lack of a direct relationship between these two systems can be further illustrated in the following example from the Eastern Region, using an ECS as a substitute for established seed transfer guidelines.

Stand or provenance differences in conifer species are best described in magnitude by thousands of square miles. The scale that "best" fits that size of magnitude in an ECS is the section level. When seed zone boundaries (FSH 2409.26f) are superimposed over section boundaries in the Lake States, there are no meaningful linkages or similar geographic boundaries. As an example, there are parts of three sections (16, 22, and 13) encompassed by the most southern seed zone of breeding zone B in northern Wisconsin (Figure 1). There is no biological basis for further subdividing this seed zone into three additional sub-seed zones defined by section boundaries. The application of sections or smaller scales within an ECS artificially manages the patterns of genetic variation of tree species and unnecessarily limits the flexibility of available seed sources for reforestation. Ecologic and genetic classification systems are based on different factors and operate at different scales. An ECS regardless of scale, should not be used in guiding seed movement when genetic data are available.

The discussion thus far has focused on scale and geographic boundaries, i.e., two-dimensional concepts. Slightly different conditions exist in Inland West conifers. Patterns of genetic variation for adaptive traits are best described in three dimensions. These patterns of variability are summarized in seed transfer guidelines and breeding zones for tree improvement programs based on significant changes elevation, latitude, and longitude (Rehfeldt 1990). Attempting to apply a zonal, or two-dimensional approach to a three-dimensional system can be characterized as another example of artificially managing single species. Meaningful patterns of genetic variation are predominantly based on changes in elevation and to a lesser extent, geographic distance.

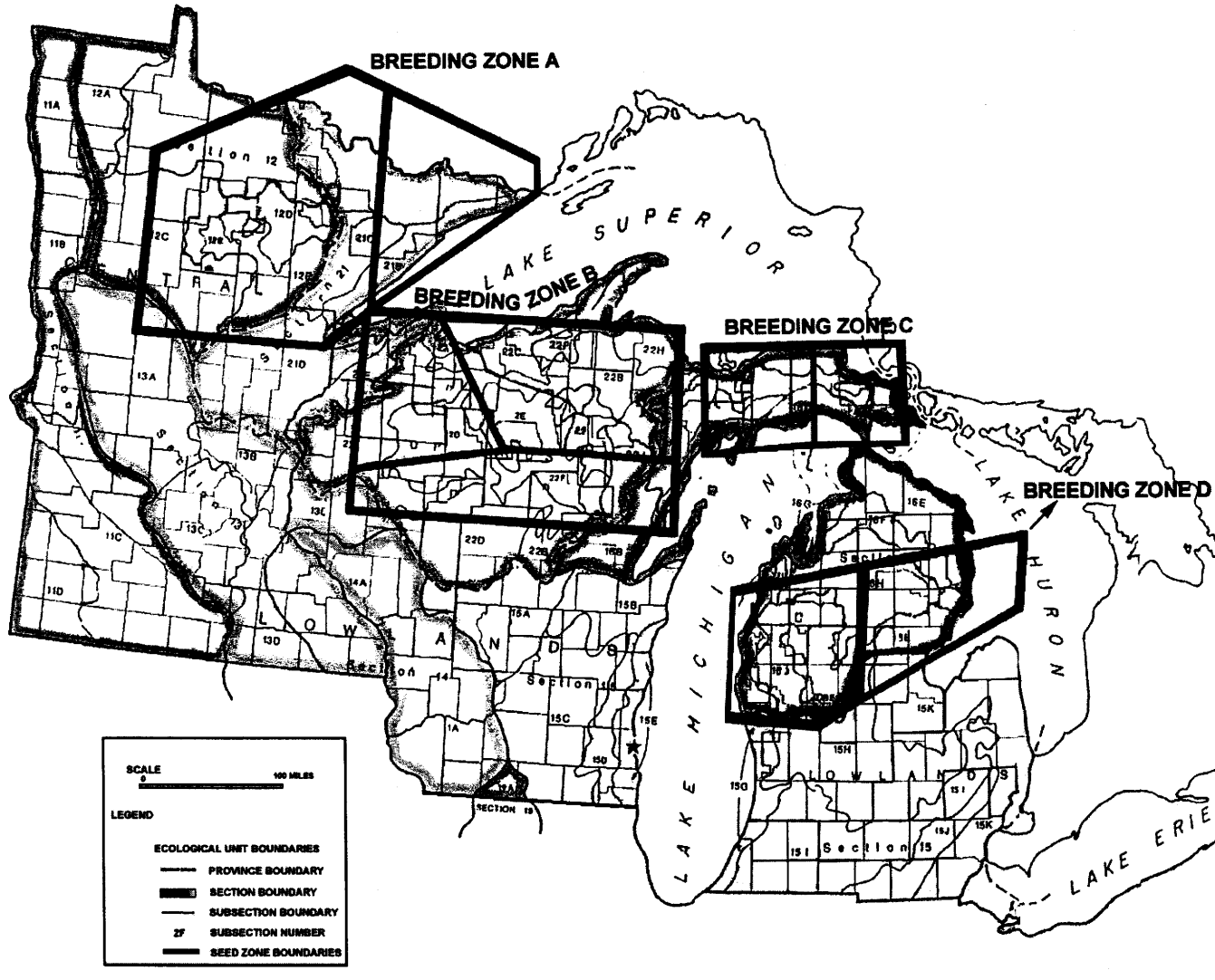

Figure 1.—Lake States breeding and seed zones superimposed on sections of the ecological classification system, USDA Forest Service Eastern Region.

Single-Factor Coarse Filters and Seed Transfer

Another proposed seed transfer method for individual species involves a coarse-filter approach using similar climatic zones, referred to as homoclines (Rauscher 1983). In this example, breeding and seed zones are again superimposed over homoclines in the Lake States (Figure 2). The use of climatic zones is too liberal of an approach to guide seed movement. For example, seed from homocline #14 in Michigan can be transferred to homocline #14 in Wisconsin.

An historic example of this type of liberal seed transfer involves jack pine seed putatively from Michigan, planted during the 1930s on the Chequamegon National Forest in Wisconsin. It was during this time that seed was in short supply and the development of seed transfer guidelines was still in its infancy. Beginning in the late 1980s, silviculturists began to note that jack pine around the Sunken Camp area began to prematurely exhibit signs of decline and over-maturation. Subsequent analysis of these populations relative to local seed sources pointed towards a problem of an off-site seed source[2]. It is likely that this problem could have been avoided by using locally adapted seed. Using climatic zones or homoclines as a surrogate for seed transfer is also, not recommended when genetic data are available.

Native Plants and Species Recovery Programs

Broad-scale assessments and coarse filters become more useful in genetic resource programs for species lacking genetic information for adaptive characters. These assessments and coarse filters have the potential to provide a first-cut at seed transfer guidelines in native plant programs. The goal however, should be to continue to work towards defining seed transfer guidelines based on genetic data for adaptive characters (Rehfeldt 1990).

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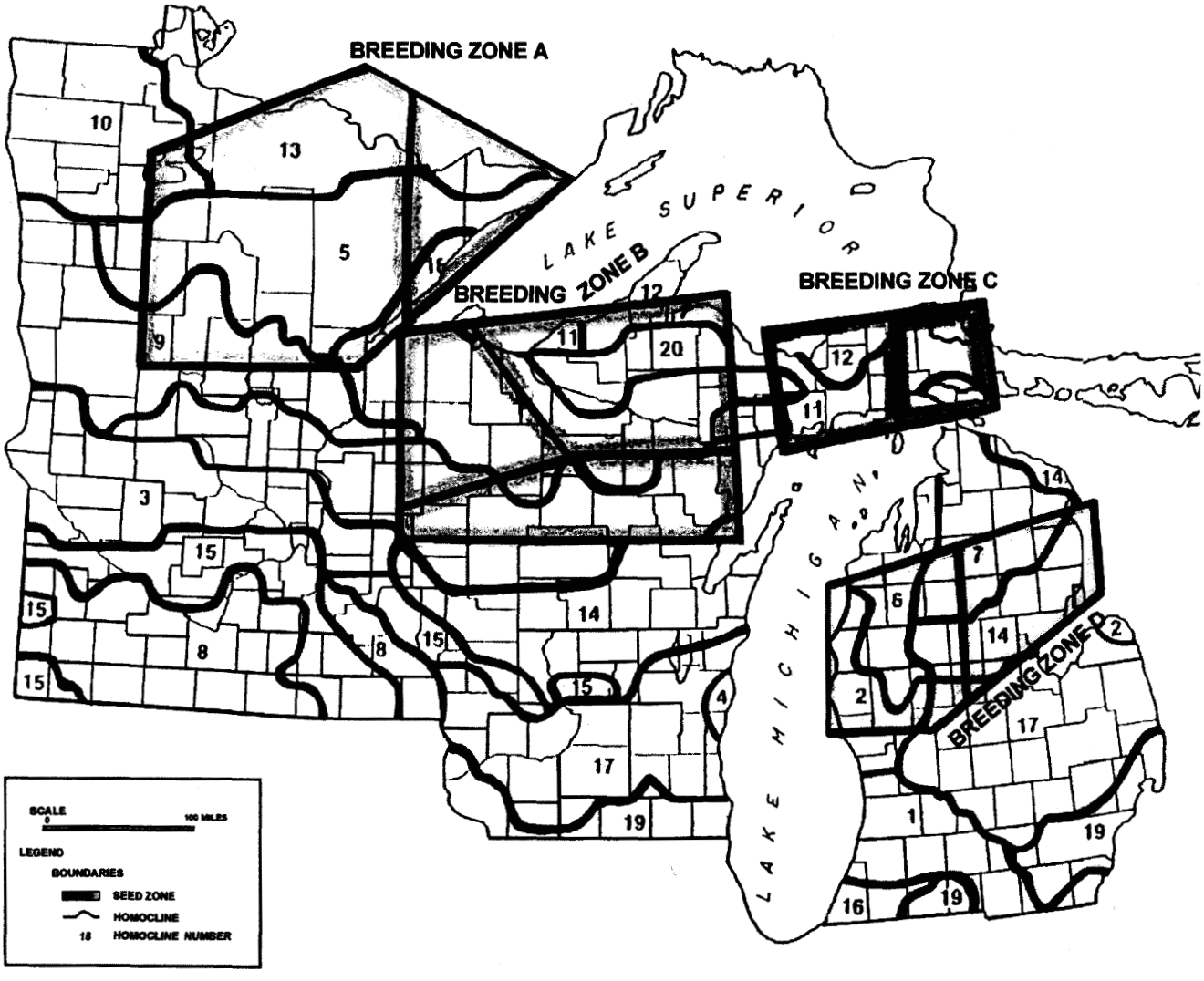

Figure 2.—Lake States breeding and seed zones superimposed on Lake States homoclines (Rauscher 1983), USDA Forest Service Eastern Region.

Characterization of habitat types for Kirkland's warbler in Michigan and Karner Blue butterfly in Minnesota has made the Lake States' ECS particularly useful in identifying unknown populations for census surveys of rare species. Perpetuation of rare species however, is determined as much by the system of genetic variability as it is by habitat availability (Rehfeldt 1990). Geographic distributions and population demographics are not adequate predictors of genetic structure; designed genetic experiments remain the most reliable means of understanding patterns of genetic variation (Rehfeldt 1997). Recovery programs are just beginning to go beyond a demographic approach (census number, breeding pairs, and life histories) to a population viability analysis (Murphy et al. 1990), incorporating patterns of genetic variation that infer an adaptive advantage with threatened, endangered and sensitive species.

Conservation of genetic diversity, restoration of target species, and improving forest health require land managers and geneticists to focus on important biological levels within the genetic hierarchical system, which infer insect and disease resistance and adaptation. Broad-scale assessments and coarse filters are not recommended for managing the genetic resource of individual species, except as a temporary measure until genetic data become available. The last topic of this paper presents a means of capturing these concepts in land management decisions as it relates to genetic resources.

FOREST PLAN REVISIONS

An appropriate landscape-level unit is necessary for guiding Forest Plan revisions. Recent discussions within the Forest Service have focused on a planning unit roughly the size of hundreds to thousands of acres. This scale corresponds to the landtype association level with an ecological classification system. From a perspective of managing genetic resources, there are concerns of applying this small

Table 2.—Role of genetic resources within a proposed Record of Decision

VI. THE DECISION

Some major aspects of the Decision are:
Timber Supply, Forest Health, Restoration...

Consequences of using improved vs. unimproved seedlings:

Western White Pine

Woodsrun	Little or no blister rust resistance; unknown achievement in conservation goals; unreliable seed source.
Phase I	65 percent blister rust resistant; does not meet conservation goals due to limited genetic base; medium to high risk of losing single-gene resistance; reliable seed source.
Phase II	100 percent blister rust resistant; exceeds conservation goals; medium to low risk of losing resistance; reliable seed source.

Western Larch

Woodsrun	No improvement in cold hardiness, *Meria* needle cast resistance or height-growth; unknown achievement in conservation goals; highly *unreliable* seed source.
Phase I and II	Gains of 15-20 percent increase in cold hardiness, 5-15 percent increase in *Meria* needle cast resistance, and 20-30 percent improvement in early height-growth; exceeds conservation goals; reliable seed source.

Citations can continue with other species, e.g, ponderosa pine, Douglas-fir, lodgepole pine, based on regional tree improvement program emphasis.

of a scale relative to the larger scales that best describe meaningful patterns of genetic variation for individual species. Land managers need to make an extra effort to consider the implications of scale and place this in the context of managing and conserving the genetic structure of forest tree populations.

For planning purposes, a possible solution to bridge the gap between large-scale assessments or vegetation task groups that design protocols for ecological pattern and process, is to develop GIS layers based on genetic data for priority species. These genetic layers can be used to identify coincident polygons to link to a TSMRS database or to the Satellite Imagery Landcover Classification system. For the Northern Region, this approach would require 32 layers to reflect the three-dimensional patterns of genetic variation for western white pine, western larch, ponderosa pine, Douglas-fir, and lodgepole pine. Such an approach would help to standardize protocols among a broader sample of program areas, without having to rely on genetics terminology.

Another issue in Forest Plan revisions is a long-term commitment to tree improvement programs to help meet objectives of sustainable ecosystems, improved forest health, and conservation of biodiversity. Genetic programs are becoming increasingly vulnerable to reduced budgets and pressures to meet reforestation and timber stand improvement targets. Additional pressures on genetic resource programs can also occur when silvicultural projects are considered for non-commercial tree species or for lands classified as unsuitable. These pressures diminish the capacity of genetic resource programs to play a vital role in ecosystem management.

Tree improvement also has the potential to play a more visible role in the forest planning process. Several sections in Environmental Impact Statements, Record of Decisions and Forest Plans can emphasize the consequences of proposed actions on genetic resources: 'Introduction and Goals', 'Vision for the Future', 'The Decision,' and 'Alternatives Considered' (USDA Forest Service, Clearwater National Forest Record of Decision and Forest Plan 1987). Possible examples for the Northern Region are summarized in a hypothetical Record of Decision in Table 2. This information can be further expanded upon in the text of individual Forest Plans.

The basic premise is to document the consequences of 'Action vs. No Action' in identifying gains in production seed orchards based on insect and disease resistance and cold hardiness, to meet forest health and conservation of genetic diversity objectives. Seed orchards provide a more reliable seed source of higher seed yields and seed quality over woodsrun collections. Seed orchards serve a primary role in restoring lands decimated by fire, insects and diseases, particularly when natural regeneration is insufficient or inappropriate. Internal and external customers need to be made aware that without the genetic material in progeny tests or seed orchards, federal lands become vulnerable when entire collection areas of locally adapted seed sources are lost to due insects, diseases, or catastrophic fire.

Gains from improved seed also increase productivity in commercial tree species. Harvest levels among the alternatives considered in land management planning can be further characterized by projected increases in productivity per acre from using genetically improved planting stock (Howe and Raettig 1985).

Important linkages between genetic resource programs and other program areas also need to be emphasized in the forest planning process. An example is the linkage among tree improvement, reforestation, integrated disease management, and timber stand improvement programs to work together to place rust resistant white pine back in Inland Northwest forests. It is implied that where there is a commitment to tree improvement, there is a commitment to reforestation programs among regions. These are simple measures to portray a more complete picture of how federally owned lands are managed in the context of ecosystem management, while employing cost-effective measures to prevent further erosion of genetic resources.

CONCLUSIONS

Benefits of tree improvement programs in managing ecosystems and improving forest health are sometimes lost in changing management paradigms and in the development of new technologies. Potential consequences of uneven-aged silvicultural prescriptions and the replacement of broad-scale assessments and single-factor filters in lieu of genetic data have serious consequences on managing the genetic resource of tree species. Tree improvement programs have an active role in developing and maintaining appropriate seed transfer guidelines, seed production areas and seed orchards (designed for improved forest health, cold hardiness, and productivity), as well as gene banks. A means of documenting these benefits internally and externally in the Agency's decision documents will more formally address the benefits derived from tree improvement programs.

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Demonstrating Vegetation Dynamics using SIMPPLLE

Glenda Scott and Jimmie D. Chew[1]

Abstract.—Understanding vegetation dynamics, both spatially and temporally, is essential to the management of natural resources. SIMPPLLE has been designed to help us quantify and communicate these concepts: What levels of process, i.e., fire or insect and disease, to expect; how they spread; what the vegetative distribution and composition is over time; and how silvicultural treatments affect the processes driving vegetative change. SIMPPLLE is applied in two forest types and used to communicate interaction of processes and vegetative patterns on specific landscapes and evaluate silvicultural strategies. Impacts on species, stand structure and probability of fire are displayed and compared to desired landscape conditions.

INTRODUCTION

Understanding vegetative dynamics is key to managing our ecosystems. SIMPPLLE is an acronym taken from **SIM**ulating Vegetative **P**atterns and **P**rocesses at **L**andscape Sca**LE**s; it is a management tool to facilitate the understanding of landscape dynamics. SIMPPLLE integrates existing knowledge of vegetative change and the processes driving change. Useful at multiple scales, from mid-scale to project level, where spatial relationships are important, it provides a bridge for analyzing stand level treatments to landscape level effects.

The model was developed as technology transfer addressing the needs of Region 1. Work was initiated during the Sustaining Ecological Systems program in the early 1990s and has evolved with the Region's current approach to Ecosystem Management. The protocol for revising Forest Plans in Region 1 recommends SIMPPLLE be used in the pattern and process assessment. Foresters with the State of Montana, BLM, and Forests in neighboring Regions have also expressed interest in this model.

PATTERN AND PROCESS

A key concept associated with SIMPPLLE is the interaction of pattern and processes. Vegetation patterns across the landscape influence the processes that will occur; likewise, process results in changes in pattern. Pattern is described as the mosaic of patches that are different in vegetation based on species, size and structure class, and density. The size and arrangement of patches becomes important in this assessment.

Succession is the most common vegetative process affecting composition and structure; however, fire was and will continue to be, a major disturbance agent in the Inland West (Camp 1996). In that context, fire suppression is also shaping vegetation. Other processes including insect outbreaks, root pathogens, windthrow and winter desiccation can be influential effects. To understand vegetation dynamics, it is important to consider these types of processes and the probability for occurrence. Low probability events commonly have the largest effect on shaping the vegetative mosaic.

The temporal effects on vegetation is an important aspect of the pattern and process assessment. Current and historic photographs such as those in *Fire and Vegetative Trends in the Northern Rockies* (Gruell 1983) help to communicate vegetation changes. These provide documentation of the effects of processes and the resulting patterns that have occurred. Photo records, however, fall short in predicting the look of the landscape in the future.

SIMPPLLE simulates the interaction of patterns and processes over time to predict future landscape conditions and the levels of processes, and to establish the range of variation.

COMPONENTS OF SIMPPLLE

There are four basic interacting model components used in SIMPPLLE: existing vegetation; processes that change vegetation; vegetative pathways and all possible vegetative states; and, silvicultural treatments.

Existing Vegetation

Existing vegetation conditions establish the starting point of each polygon modeled on the landscape. The following attributes are used to describe existing condition: 1) dominant species or species mix; 2) structure as an indication of developmental stage; and, 3) density. Data for the existing condition stems from attributes in inventory data bases. A GIS coverage for the existing vegetation is needed to provide the spatial attributes of adjacent polygons.

Vegetative Processes

Vegetative processes currently assessed in the model are succession (stand development), mountain pine beetle, western spruce budworm, root disease and fire. The probability of occurrence for the various processes stems from a combination of experts' judgments (as in the case of fire) and available hazard rating systems (as for mountain pine beetle). The probability of occurrence is based on an initial probability that depends on individual polygon attributes, and adjusted by both the vegetative condition and the processes in adjacent polygons. This influence of adjacent polygons provides for an interaction between specific vegetation patterns and the processes. SIMPPLLE also allows for the spread of processes. Thus a polygon with low fire probability may burn in the simulation due to fire spread from an adjacent polygon. The systems user interface

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allows users to alter probabilities and resulting states and lock-in the processes to be simulated.

Vegetative Pathways

A sequence of potential vegetative states, with processes being the agents for change from one condition to another, is called a pathway. These potential states are stratified by ecological classifications such as habitat types or groups of habitat types. The potential states represent different conditions for species, structure or density. The specific combinations used depends on what is needed to capture the dynamics of processes and to provide detail to address the planning issues.

Silvicultural Treatments

Silvicultural treatments in SIMPPLLE are separate from the processes in the pathways. A treatment alters the state by changing the species, structure or density. It may also alter the probability of processes occurring even without changing the state.

SIMPPLLE MODELS VEGETATIVE CHANGE

Two examples of forest types in Montana were used with SIMPPLLE to model vegetative change. The data used was from Forest projects; however, the activities have been modified and management considerations simplified for this presentation. These types of simulations can be valuable in communicating historic range of conditions, the trends of the existing vegetation, and to understand the influence of silvicultural treatments in moving towards desired landscape conditions.

Ponderosa Pine Forest

Forest condition. The lower east slopes of the Bitterroot Mountains are ponderosa pine (*Pinus ponderosa* Dougl. ex. Laws.) and Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Beissn) Franco) forests. Ponderosa pine is climax at the lower limits of coniferous forests and seral in higher elevations. Along the Bitterroot face, it is a long-lived seral. Commonly, Douglas-fir grows in association with ponderosa pine as elevation increases. Ponderosa pine, and to a lesser extent Douglas-fir, possesses thick bark that offers it protection from fire damage. Young ponderosa pine, Douglas-fir, and other competing species are less fire tolerant. In low elevations, and with historic fire cycles, ponderosa pine was maintained in open conditions over large areas. Observations from the Selway-Bitterroot Wilderness study indicate that the most common fires were low intensity with variable severity (Saveland 1987). These fires thinned the stand from below, favoring larger ponderosa pine. On the higher slopes, Douglas-fir may have been more dominant but they were also in open stand conditions.

Without fire or other disturbance mechanisms, ponderosa pine stands tend to increase in density and develop multiple canopies. A shift to more tolerant species also tends to occur. With these changing stand conditions, the occurrence of stand replacing crown fires increases, replacing the light or mixed intensity fires in frequency and acres burned. This shift in fire regime also affects understory vegetation, litter composition, and nutrient availability.

The Bitterroot Valley is composed of agricultural lands at lower elevations, a portion of which was once ponderosa pine forests. Today, private lands border the Bitterroot National Forest. Homes and other urban developments are creeping into the dense forested lands, creating an urban interface fire risk that concerns the public and Forest managers.

Based on these forest conditions and concerns, an aspect of the Desired Condition is to reduce fire risk and provide better protection potential to homes, and protect the viewshed from wildfire. The following SIMPPLLE simulations display the stand level conditions on the landscape, vegetation trends, and the effects of silvicultural strategies on the landscape conditions.

Displays using SIMPPLLE. The Stevi West Central project area covers approximately 60,000 acres (24,282 hectares). SIMPPLLE was used to compare cover types, density levels, and size and structure composition across the landscape at various time periods. Although it was not obvious when viewing the maps, there was an increasing trend of tolerant species in the next 50 years, from 11 percent to 15 percent and increasing density. More obvious, however, was the change in size and structural stages.

The current size and structure distribution is displayed in figure 1 and future structure in 50 years is shown in figure 2. The only management action simulated was the current practice of fire suppression.

As a comparison, the reference condition size and structure class are displayed in figure 3. In this simulation, a reference condition was identified by projecting the current condition into the future to a point where the effects of fire suppression were eliminated and natural processes had returned, thus representing the range of variation under historic fire regimes. Numerous stochastic runs would establish a range of conditions, which would be useful in establishing a context for desired conditions.

Further analysis would help quantify the changes in pattern and patch sizes of the landscape conditions. It appears that there are more continuous patches of multi-story and two story stand conditions in the future condition simulation than in either the current or reference condition. This is consistent with the stand development expected in ponderosa pine relative to fire regimes.

The relative composition by size and structure class is shown in figure 4. The current condition shows 13 percent multi-storied stands; in 5 decades that would increase to 31 percent (multi- and two storied stands) based on one simulation.

SIMPPLLE also can be used to predict the level of processes likely to occur under different scenarios. Based on numerous runs, fire levels are predicted over time and displayed in figure 5. The current regime is represented in about the first 15 decades. After that, the effects of fire suppression decline, and

by decade 40 it appears that stand conditions have returned to historic conditions and historic fire regimes are functioning. Fewer acres are burned by stand replacement fire however, significantly more acres are burned by mixed intensity fires. The management goal is not to mimic this fire cycle per se, but to move towards conditions that were maintained by these fire regimes. A fire start in these conditions will more likely be less intense and more controllable.

Based on an understanding of the processes and vegetative conditions, silvicultural treatments were designed to increase diversity and lower fuel loads along the lower slopes. Although a mix of stand conditions is desirable, this example emphasizes treatment in the ponderosa pine forest types to reduce canopy layers and ladder fuels. These types of stands are most dominant on the eastern portion of the landscape, west of the large non-stocked agricultural lands. The target stands would be open grown, dominated by larger ponderosa pine and Douglas-fir. There would be small areas of young trees, but stand replacement fire would be low risk.

Silvicultural treatments include thinning from below and underburning to favor large ponderosa pine and repeated to maintain conditions similar to the historic fire regimes. The level of treatments that were simulated are shown in figure 6. Thinning was accomplished on all stands that would benefit in the first decade. Underburning, however, was repeated in the following five decades to maintain the desired stand conditions.

The resulting size and structure class composition of the landscape (figure 7) is compared with the simulation of future condition with only fire suppression in place (from figure 4). The result is a 6 percent decline in the combination of multi-storied and two-storied conditions. Assuming this provides a mosaic of size and structure types, it is observed that silvicultural treatments are moving the landscape towards the desired condition. It is also observed that major changes to landscape conditions require rather intensive levels of management activities.

Lodgepole Pine Forest

Forest condition. Lodgepole pine (*Pinus contorta* Doug.) grows in association with many western conifers. It tends to dominate in even-aged stands. In this example on the Helena National Forest, lodgepole pine is seral to more tolerant alpine fir and other species, however it will maintain site dominance for over 100 years. Large expanses of lodgepole pine were historically common, with a mosaic of young and later successional lodgepole pine patches as a result of varying disturbances. The current trend, however, is a decline in diversity with large expanses of lodgepole pine being similar in structure and density. It is not uncommon to see entire drainages moving in this direction. In short, the historic mosaic that provided resiliency and diversity is being lost.

Mountain pine beetle (*Dendroctonus ponderosae* Hopk.) has played a historic role in lodgepole pine ecology. When

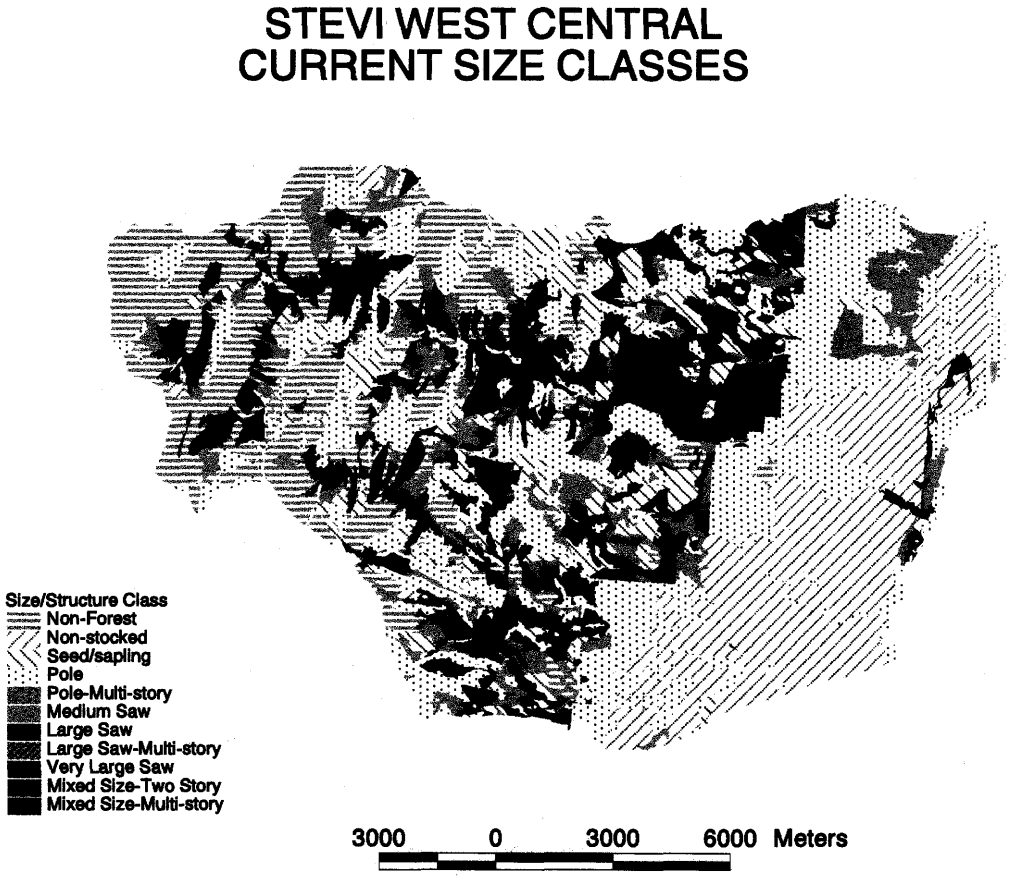

Figure 1.—Distribution of the Current Condition size and structure classes in the Stevi West Central project area. (Single story structure except as noted in legend.)

STEVI WEST CENTRAL
FUTURE CONDITION SIZE CLASSES

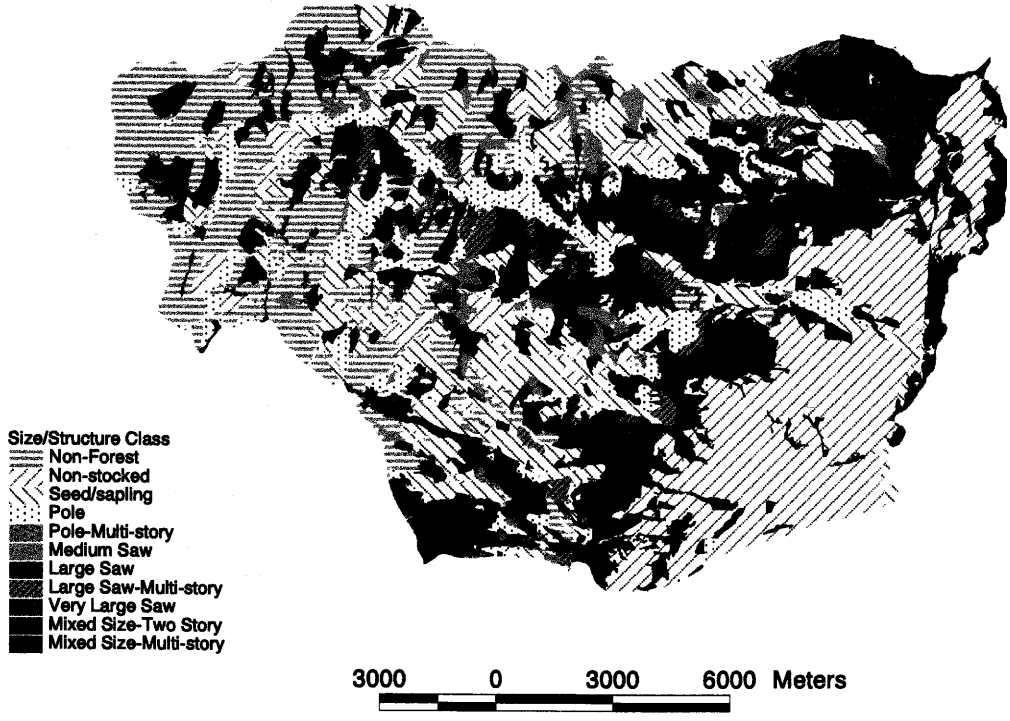

Figure 2.—Simulation of Future Condition in 50 years displaying size and structure classes with the only management activity being the current fire suppression. (Single story structure except as noted in legend.)

STEVI WEST CENTRAL
REFERENCE CONDITION SIZE CLASSES

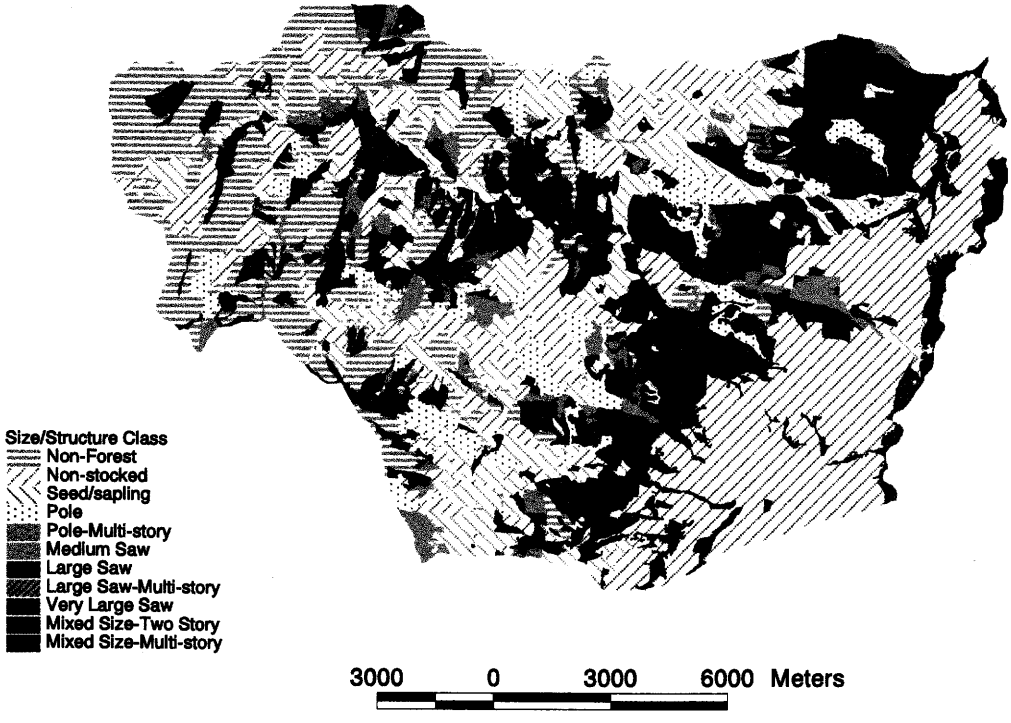

Figure 3.—Simulation of Reference Condition displaying distribution of size and structure classes. (Single story structure except as noted in legend.)

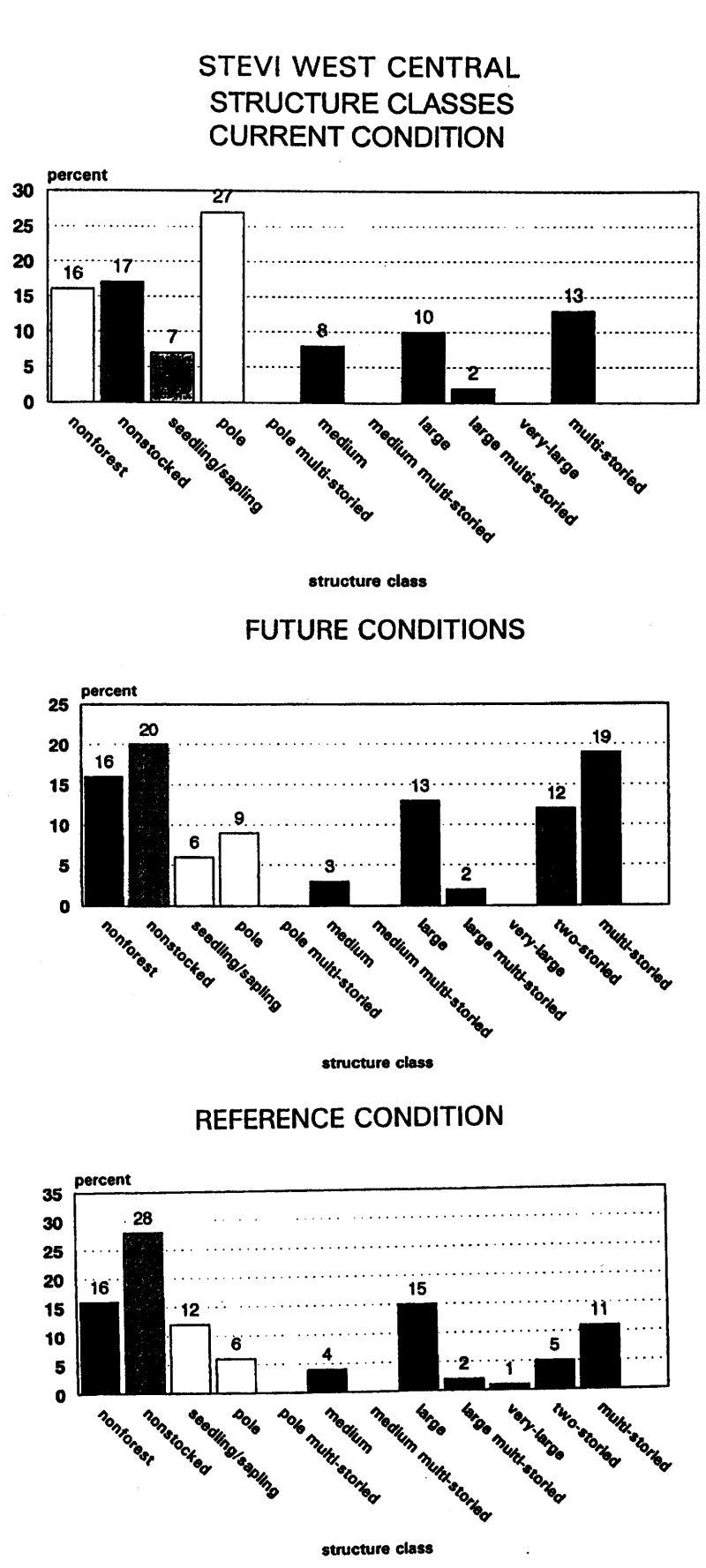

Figure 4.—Comparison of the size and structure classes in the three conditions: Current, Future (fire suppression only), and Reference Condition.

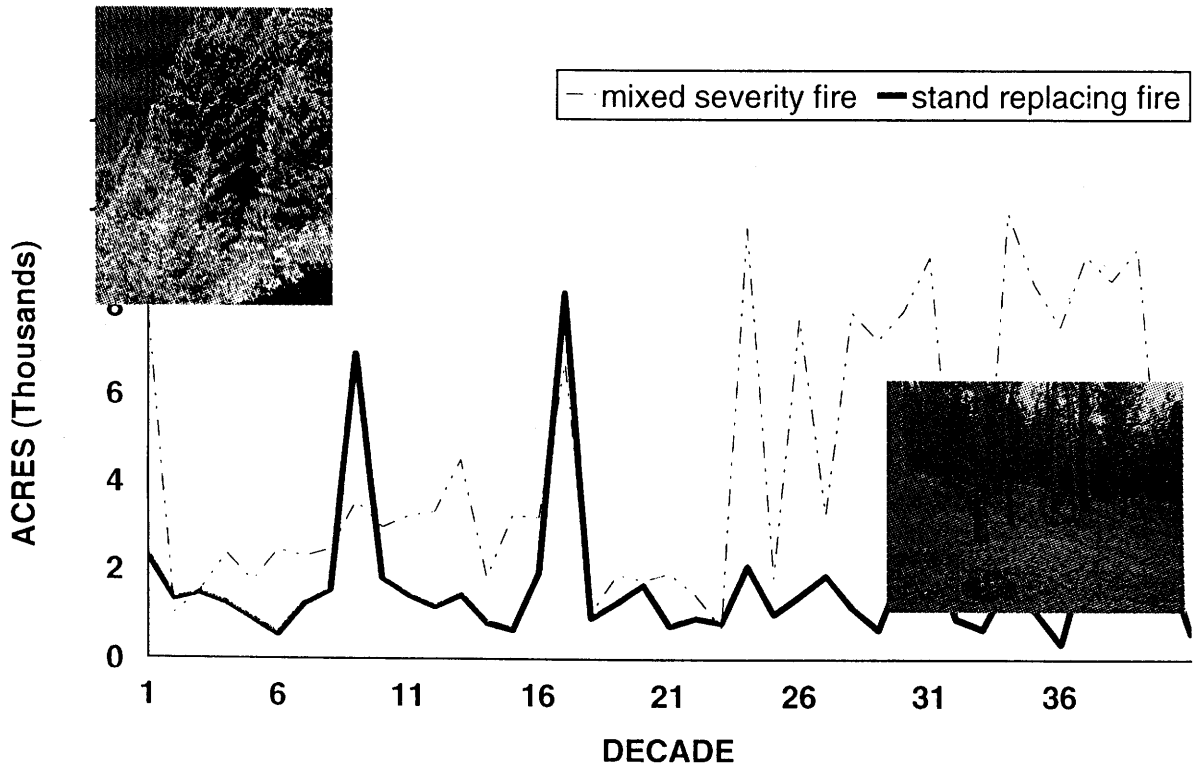

Figure 5.—Prediction of fire levels for 40 decades with fire suppression not in practice. The effects of past fire suppression are greatest in the first 10 to 15 decades. By the 40th decade, historic fire regimes are assumed to be functioning.

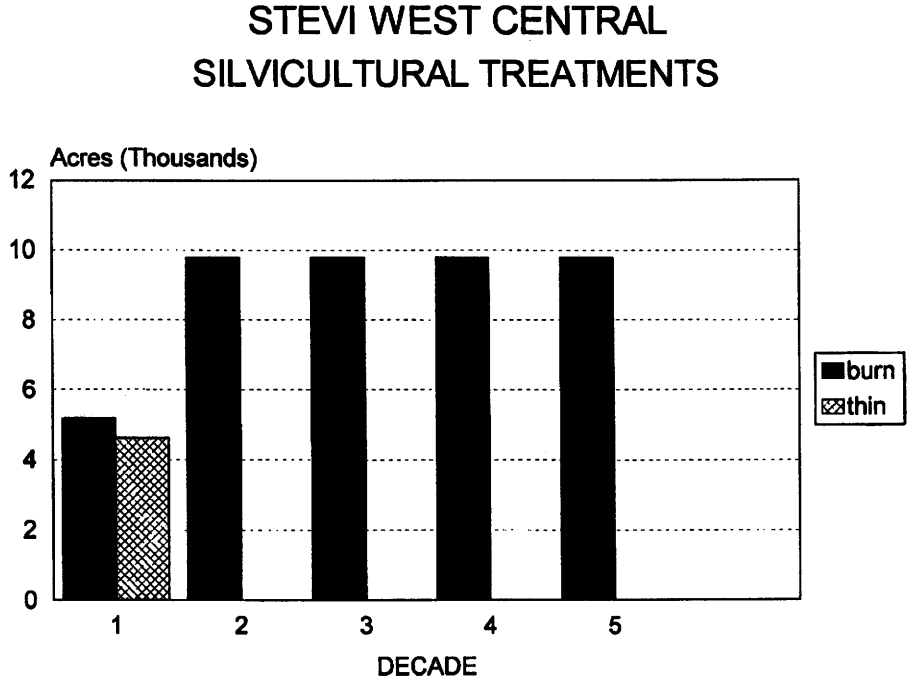

Figure 6.—Levels of silvicultural treatments applied in the ponderosa pine forest types to alter stand structure and composition. All "necessary" thinning is accomplished in the first decade. Underburning activities applied for 5 decades.

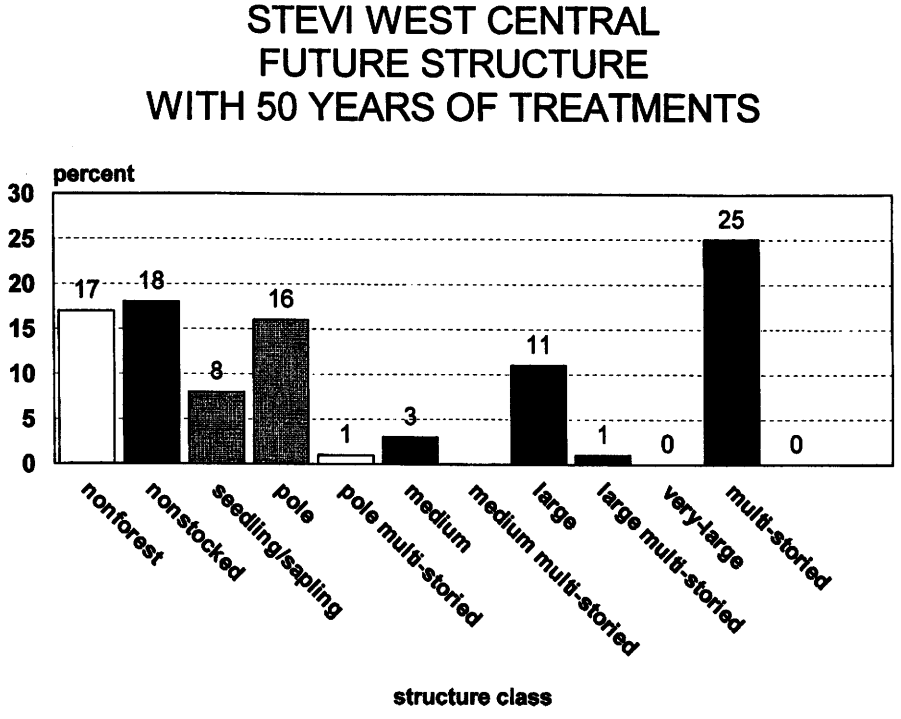

Figure 7.—Simulation of Future Condition in 50 years with the thinning and underburning activities applied.

weather conditions are favorable, susceptible stands of lodgepole pine can be infected by mountain pine beetle. Depending on the continuum of susceptible stands and other factors, the mortality may be endemic or at epidemic levels. The more continuous the susceptible stands, the greater the areas of mortality.

Fire is also common in lodgepole pine forests with or without mountain pine beetle mortality. With heavy mortality from mountain pine beetle, however, the fuel loads build up even greater. Aging lodgepole pine forests compile fuels as canopies break apart and alpine fir develops as an understory ladder fuel. Eventually, built up fuels are consumed by fire. Favorable conditions for lodgepole pine regeneration is created and it is likely that lodgepole will revegetate the site at the expense of other species. The pilot study by Arno and others (1993) showed that pre-1900 fires were relatively frequent but patchy, resulting in a fine grained mosaic of young and mixed-aged lodgepole pine communities with few late successional stands dominated by fir. A decline in fire frequencies (resulting from fire suppression) across the landscape sets the stage for larger stand replacing fire events, and a coarser grained mosaic.

The continual mountain pine beetle mortality and fire cycle can be simulated with SIMPPLLE (figure 8). Mountain pine beetle mortality peaks one to two decades prior to stand replacing fire peaks.

Fire control and management activities cannot change the mountain pine beetle and fire cycle, but they can affect the patterns that these processes affect. The more continuous areas of susceptible forest result in larger areas of mortality and eventually more intense fires.

In many drainages, concerns about sensitive fish species exist. In drainages, such as Poorman Creek on the Helena National Forest, an aspect of the desired condition is to reduce the risk of catastrophic mortality to protect long term watershed conditions. Heavy mortality would intensify concerns in already stressed watersheds.

Displays using SIMPPLLE. The distribution of current vegetation conditions is displayed in figure 9 for the Poorman Implementation area; an area of 30,000 acres (12,141 hactares). This map of size and structure classes shows large expanses of lodgepole pine of varying patch sizes. The simulation of conditions in 50 years (figure 10) with fire suppression being the only management activity, shows the trend toward larger expanses of older age classes, which will result in a trend of larger fires with greater intensity.

Using SIMPPLLE, the level of fire over the next 50 years is simulated based on current stand conditions and fire suppression practices. The result is a landscape with a majority of the area likely to burn in the next 50 years (figure 11). The SIMPPLLE output report identifies poygons where fire starts occur versus polygons burned by fire spread. The polygons of fire start would be likely candidates for silvicultrual manipulation to lower the fire risk.

The overall silvicultural strategy to achieve the desired condition is to breakup the continuum of even-aged lodgepole pine (increase mosiac), improve stand vigor, and reduce ladder fuels for decreased fire risk. A combination of silvicultural treatments were simulated across the landscape including underburning and broadcast (stand replacement) burning, regeneration and intermediate harvests (figure 12).

After numerous stochastic runs, the SIMPPLLE output showed lower levels of stand replacement fire with the

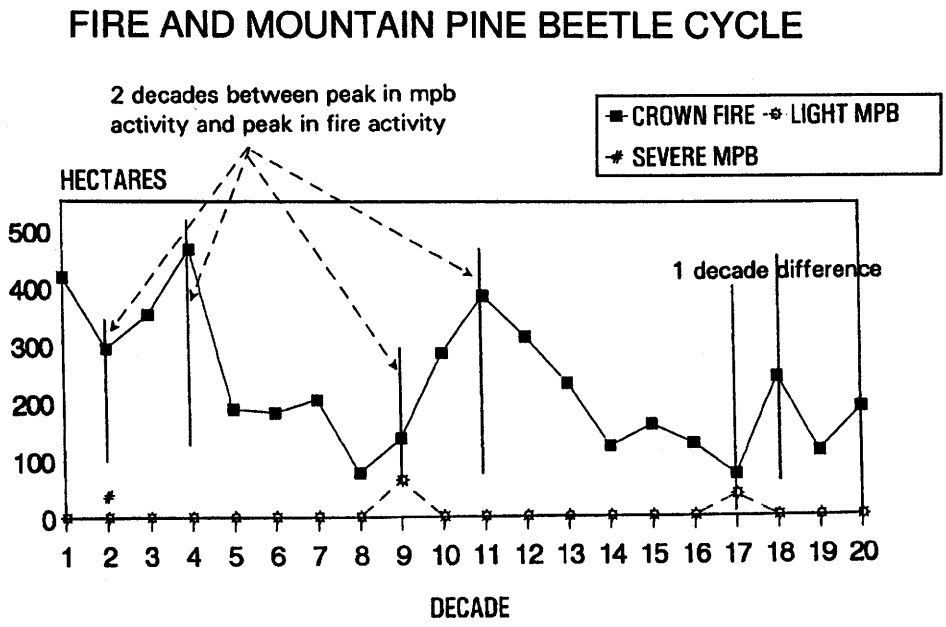

Figure 8.—Prediction of crown fire (stand replacing) and mountain pine beetle (MPB) cycles on the Coram Experimental Forest.

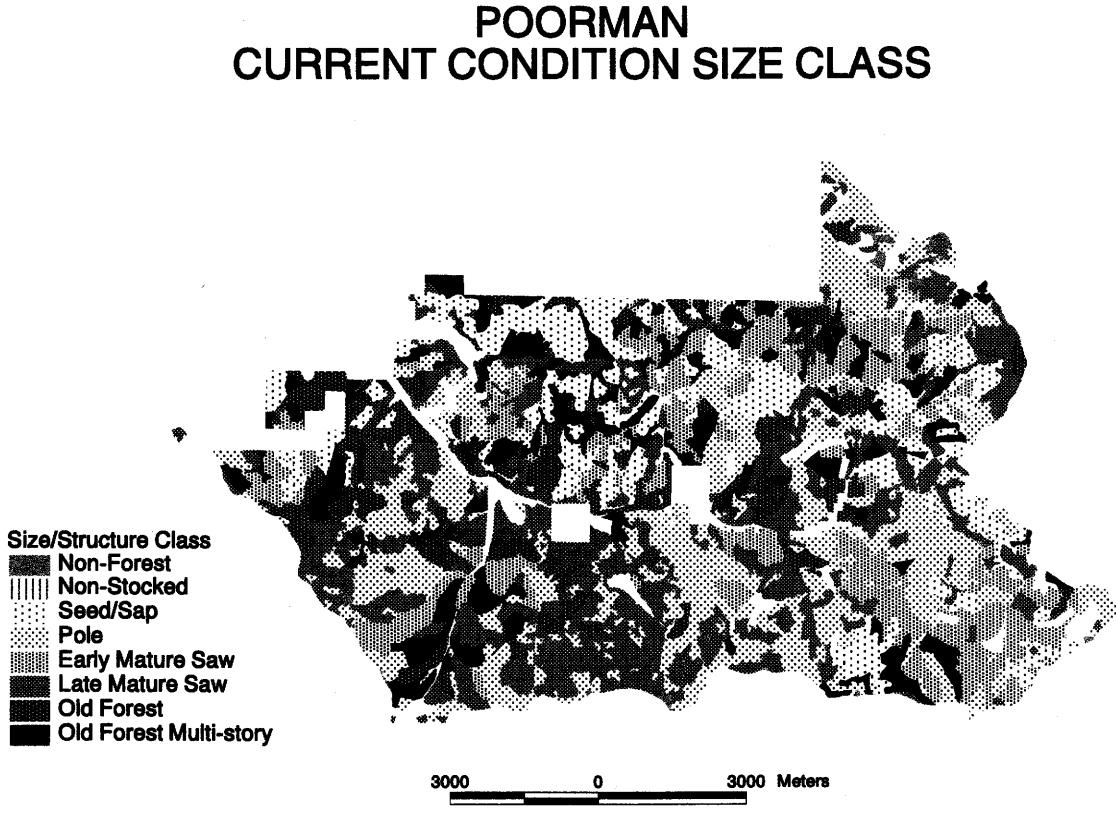

Figure 9.—Distribution of Current size and structure classes in the Poorman Project Area which is dominated by lodgepole pine. (Single story structure except as noted in legend.)

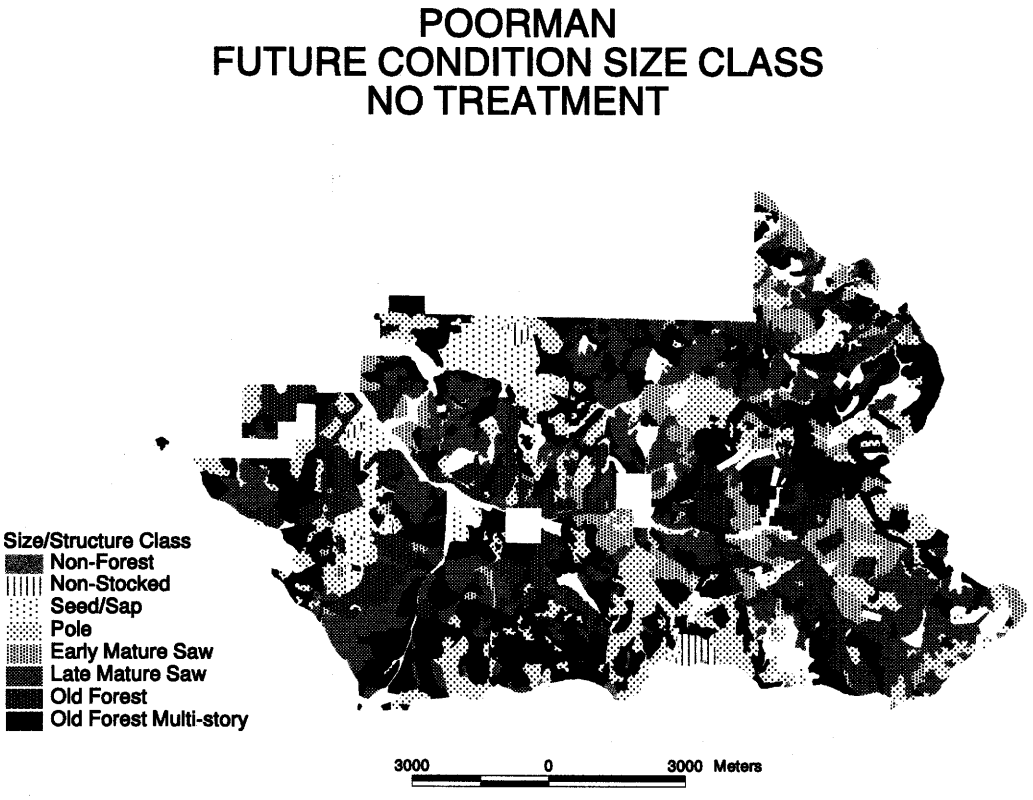

Figure 10.—Simulation of the future condition in 50 years with fire suppression being the only management activity. (Single story structure except as noted in legend.)

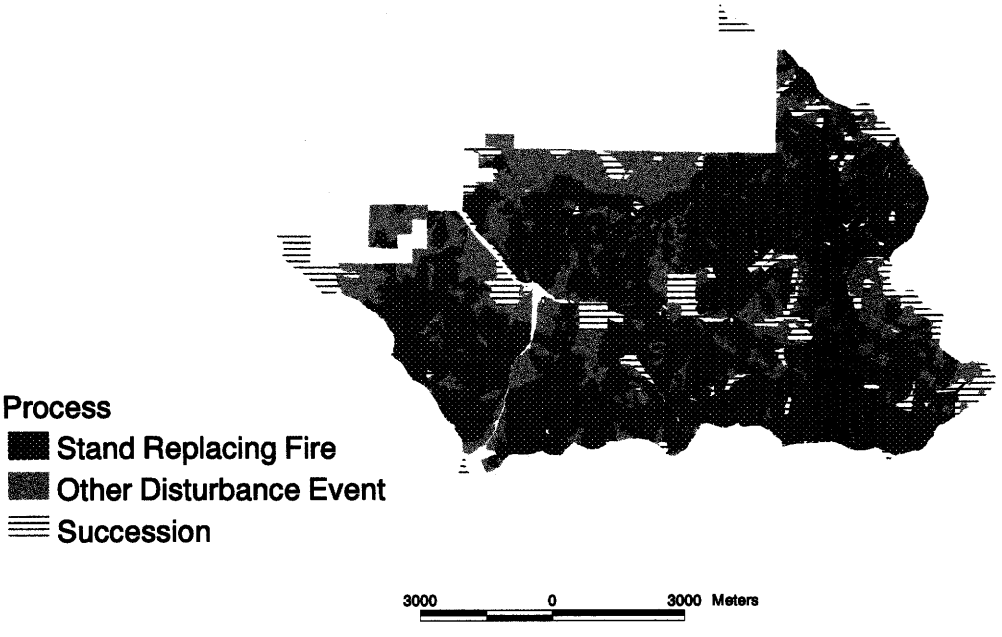

Figure 11.—Level of fire predicted over the next 50 years based on current stand conditions and fire suppression practices in place. Shaded areas represent the areas with greater than 90 percent likelihood of burning.

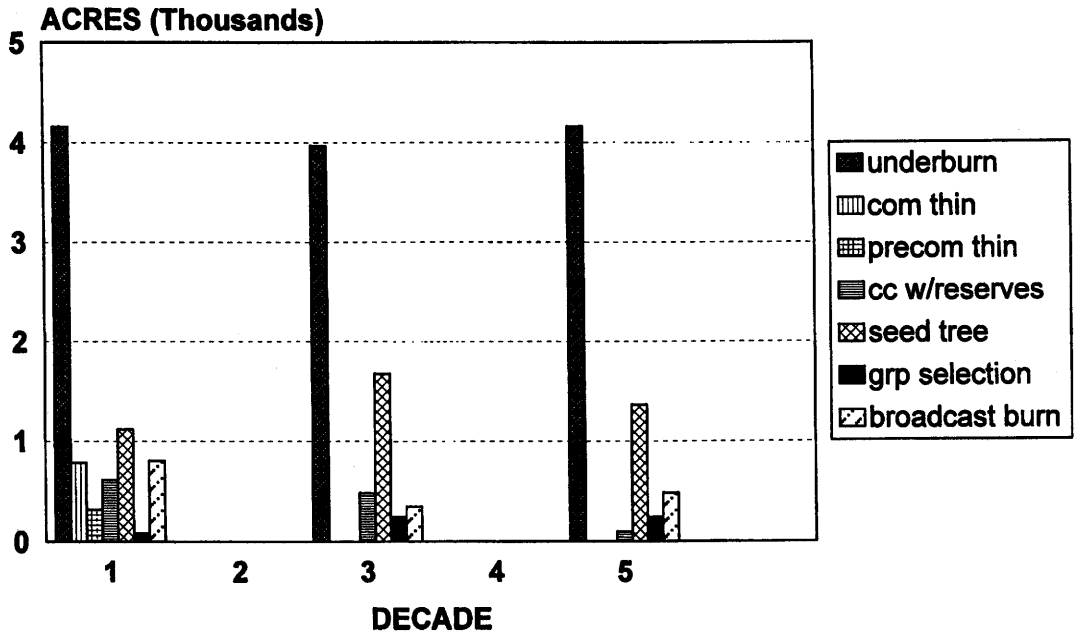

Figure 12.—Level of silvicultural treatments applied to modify stand species and size class to move towards the desired vegetative conditions. This is alternative B in the Poorman project.

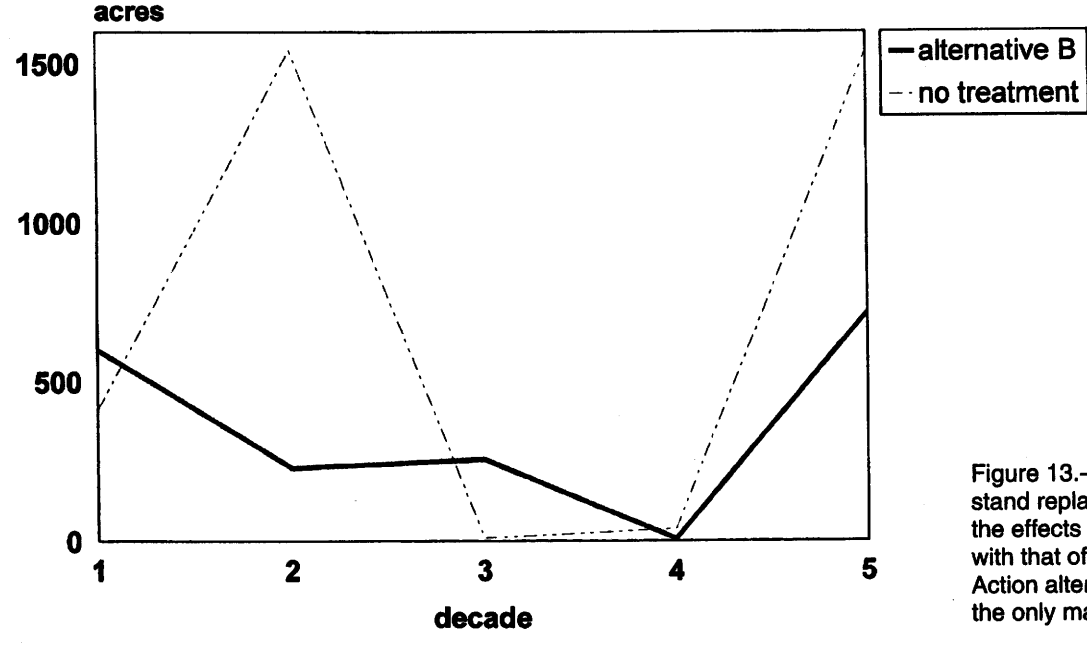

Figure 13.—Prediction of the levels of stand replacement fires comparing the effects of applying Alternative B with that of No Action. Under the No Action alternative, fire suppression is the only management activity.

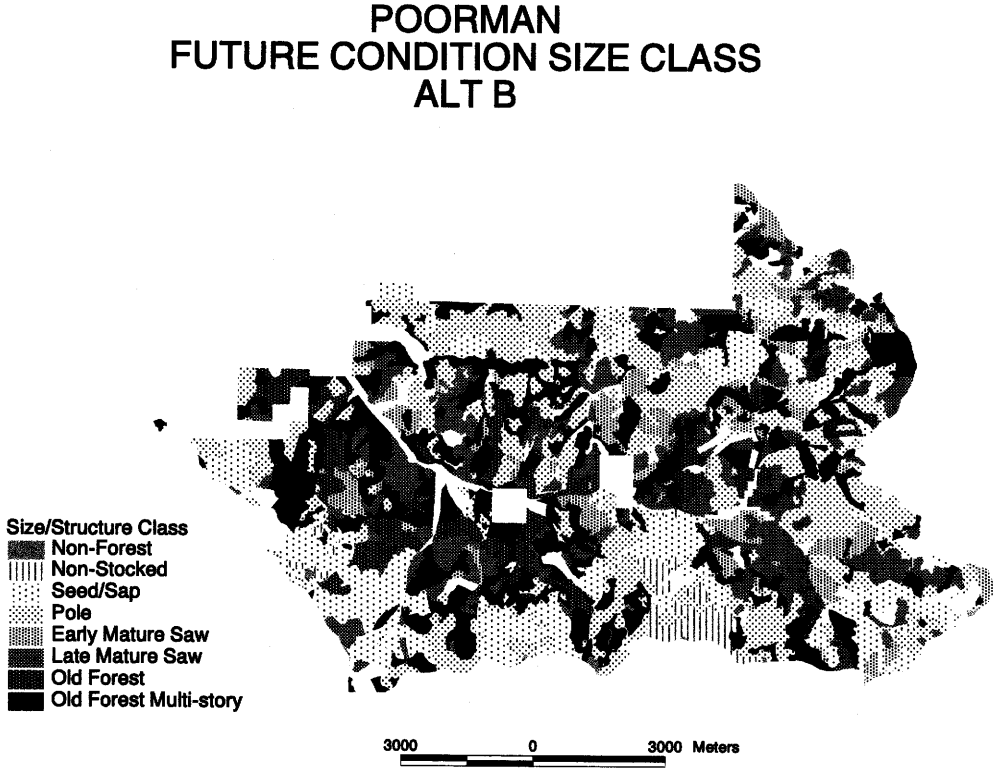

Figure 14.—Simulation of resulting Size and Structure Composition 50 years in future with the silvicultural practices applied. (Single story structure except as noted in legend.)

silvicultural activities applied. As see in figure 13, fewer acres are predicted to burn each decade.

The resulting structural diversity displayed in figure 14 is also more desirable, representing the patchy distribution common during historic fire regimes. The silvicultural activities increased the compostion of young and middle age classes. As in the pondersoa pone example, affecting change on the landscape requires treating a large number of acres. However, even when treating only a third of the acres described in this example, we see the landscape moving towards desired conditions.

SIMPPLLE STATUS

The silviculturists and other resource managers in Region One are becoming familiar with the use of SIMPPLLE and are refining the logic and probabilities of the pathways and processes. The current SIMPPLLE version is linked to ARCINFO; information can be passed on to other models to quantify the fragmentation based on patch sizes, to define parameters for optimization or scheduling models, to evaluate habitat function over time and to make volume projections. The SIMPPLLE design allows for the incorporation of non-forested communities, and work has begun to incorporate a future version that will capture the interaction of vegetation and the aquatic components of the landscape.

SUMMARY

The ponderosa pine and the lodgepole pine forest examples are used to display the dynamics of forest vegetation and the effects of stand level prescriptions across the landscape using SIMPPLLE. The simulations provide a quantification of the concepts that help in understanding and communicating the range of variation of processes, the change in vegetation over time, the interaction of pattern and process, and the effects of silvicultural strategies within the context of forest ecology.

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Preparing for the Gypsy Moth — Design and Analysis for Stand Management Dorr Run, Wayne National Forest

J. J. Colbert, Phil Perry, and Bradley Onken[1]

Abstract.—As the advancing front of the gypsy moth continues its spread throughout Ohio, silviculturists on the Wayne National Forest are preparing themselves for potential gypsy moth outbreaks in the coming decade. Through a cooperative effort between the Northeastern Forest Experiment Station and Northeastern Area, Forest Health Protection, the Wayne National Forest, Ohio, is utilizing computer models to identify high-risk stands and evaluate the predicted outcome of several management options. The efforts involve the Stand-Damage Model, a portion of the Gypsy Moth Life System Model and GypsES, a decision support system that provides the transport and storage medium for the forest inventory data used in analysis and stand mapping capabilities. The process involves identifying high-risk stands and simulating development of these stands forward from the inventory year to 1997. A series of three simulations were designed to assess the range of possible tree mortality from none, to light, to heavy outbreak scenarios. If a stand contains sufficient growing stock, a simulated pre-salvage thinning was conducted using two alternative criteria. Stands with a relative stand density greater than 70 percent were cut to 60, and stands with relative stand density greater than 90 percent were cut to 80 percent. Results are given in terms of stem counts, basal area, volumes, and present dollar values. Results show the savings that could be expected if outbreaks occur following these silvicultural treatments and help to prioritize treatment schedules. The results will be used in the decisionmaking process, are documented in an Environmental Assessment as a means to inform the public as to the consequences of each proposed alternative, and will be used in the implementation of site-specific management alternatives.

INTRODUCTION

Gypsy moth (*Lymantria dispar* L.) has been spreading from its origin of introduction into North America and is currently established in western Pennsylvania, most of West Virginia, and northeastern Ohio (Liebhold et al. 1997). Gypsy moth is expected to become established in and around the Wayne National Forest in the coming decade: 1998-2007 (Fig. 1). New gypsy moth populations cause significant damage, due in part to the lack of co-establishment of its full natural enemy complex. It is expected that losses will occur in Ohio similar to those found over the past two decades in western Pennsylvania. The part of the Wayne National Forest that is of greatest concern to the forest silvicultural staff is the Dorr Run Area because this area has the highest proportion of high-hazard stands. The Dorr Run Area is located on the Athens Ranger District in Green and Ward Townships, Hocking County, Ohio, in the unglaciated Allegheny Plateau.

Because of the dense stocking, growth has slowed on a large number of trees. Gypsy moths have been trapped at increasing rates in Hocking and surrounding counties for several years. It is expected that gypsy moths could have a serious impact in this area because of the high proportion of oak and other preferred species and the generally over-stocked and low-vigor conditions that exist in many of the stands. Some mortality of oak trees is beginning to occur from shoestring root rot (*Armillaria mellea*) and twolined chestnut borer (*Agrilus bilineatus*).

Land management objectives for the Dorr Run Project Area are described in the Wayne National Forest Land and Resource Management Plan (USDA Forest Service 1988[2]). The objectives for this management area are to maintain wildlife habitat diversity, provide high-quality hardwoods on a sustained yield basis, provide various dispersed recreation opportunities, and provide off-road vehicle use.

Because of the foregoing forest health conditions and to implement the Land and Resource Management Plan, the Dorr Run Area was selected for analysis and development of vegetation management proposals. The purpose and need of the Dorr Run project is to maintain and improve forest health. Thomas (1996)[3] characterized healthy forests as "...those where biotic and abiotic influences do not seriously threaten resource management objectives, now or in the future, nor do resource management activities seriously threaten sustainability or biodiversity."

This project was a joint effort among all three branches of the USDA Forest Service. The Wayne National Forest was interested in determining what damage could occur from gypsy moth defoliation. There was interest in using the results of the Gypsy Moth Stand-Damage Model in an environmental analysis to explain to the public what the potential damage could be from gypsy moth defoliation for each of the alternatives. In addition, the data produced for individual stands would be valuable in prescribing silvicultural treatments and developing marking guidelines for specific stands. Research was interested in this project to demonstrate new modelling technology and to investigate a

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[2]U. S. Department of Agriculture, Forest Service. 1988. Land and Resource Management Plan: Wayne National Forest. As amended. Wayne National Forest, 219 Columbus Road, Athens, OH 45701-1399.

[3]Thomas, Jerome. 1996. 3400 Memo of 1/25/96 on Southern Tier Forest Health Conference Call Summary. USDA, Forest Service, Eastern Region. 310 W. Wisconsin Ave., Rm. 500, Milwaukee, WI 53203.

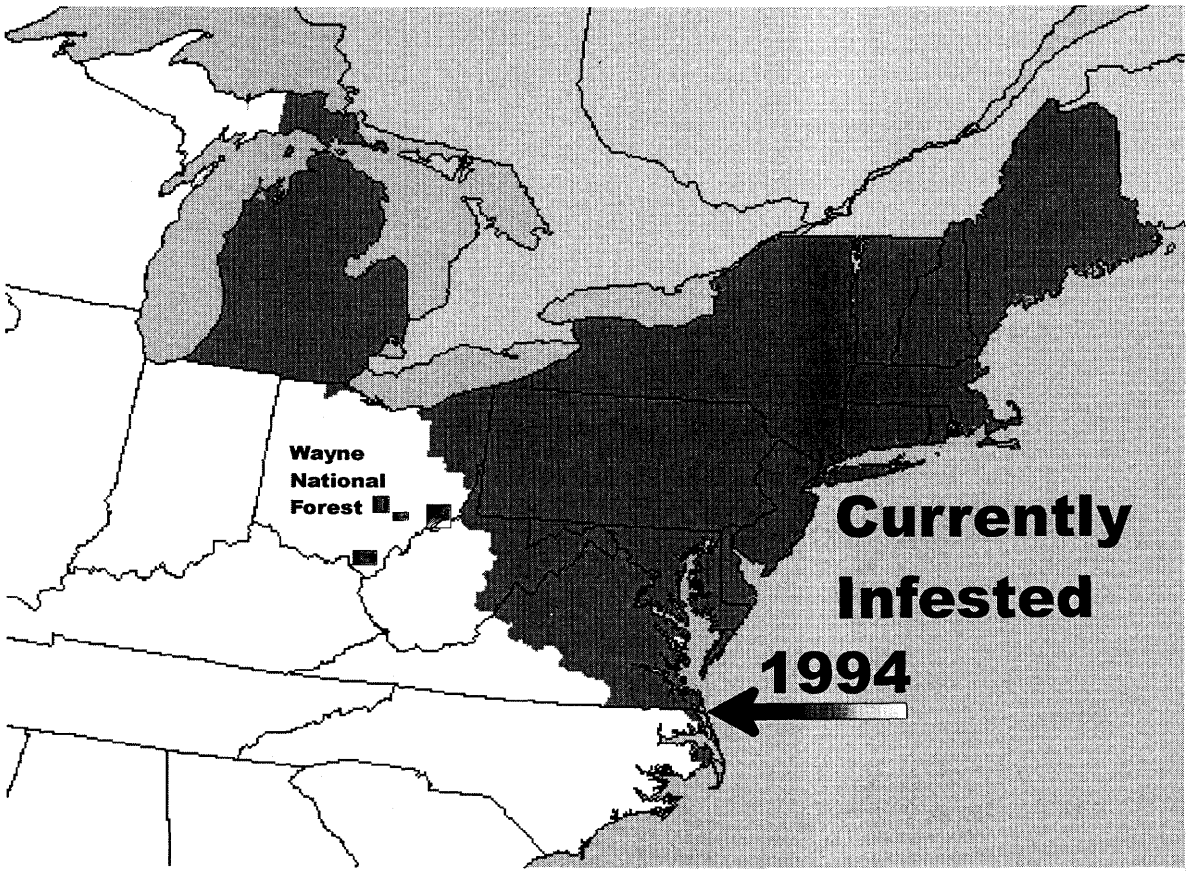

Figure 1.—Area currently infested with gypsy moth, as of 1994, and the location of the Wayne National Forest in southeastern Ohio.

significant problem using current inventory data from the Wayne National Forest. Moreover, there is a need to constantly validate models. We will be able to compare these predicted results to later actual management practices and defoliation effects, extending our knowledge of the geographic and ecological range of model applicability. State and Private Forestry's role is to coordinate between national forests and the research branches of the Forest Service, and to assist in the collection, management, and transfer of data used to support forest health assessments. Forest Health Protection's mission is to disseminate information based upon research that can be utilized not only in the management of national forests, but also on state forests and private lands.

The Environmental Assessment for the Dorr Run Project Area states that the purpose of silvicultural treatments is to "restore vigor, shape species composition, and work toward the establishment of the next forest" (USDA Forest Service 1997[4]). Five alternatives were developed and analyzed in the environmental analysis to determined how well each alternative achieved the purpose and to analyze the effects on the environment of each alternative. The analysis in this paper was utilized in documenting the environmental consequences of each of the alternatives. Silvicultural treatments were proposed to reduce damage, such as mortality or loss of mast production, by removing highly vulnerable trees before they are defoliated and die.

METHODS

Within the Dorr Run Project Area there are 5,183 acres of national forest land and approximately 3,200 acres of private land. Thirteen forest types have been identified, and six of these are oak-hickory forest types that total 3,231 acres or 62 percent of national forest land within the project area. In addition there are 39 acres of aspen stands. Oaks and aspen are preferred food species of the gypsy moth (Liebhold et al. 1995). The remaining acreage consists of a variety of non-oak hardwoods with a small amount of pine. Most of the forest in this area is greater than 60 years old, and 91 percent of this is in the oak-hickory forest types. Site Index (50-year black oak, Carmean et al. 1989) averaged 73.6 over the stands included in the initial sample and ranged from 65 to 94, with mean equal to 73 across the 24 stands used in the final analysis.

In the Dorr Run Area, oak-hickory stands are found on the more xeric sites located on ridgetops, middle to upper place

[4]U.S. Department of Agriculture, Forest Service. 1997. Environmental Assessment: Dorr Run, Hocking County, Ohio, Athens Ranger District, Wayne National Forest, March 1997. Wayne National Forest, 219 Columbus Road, Athens, OH 45701-1399. 98 p.

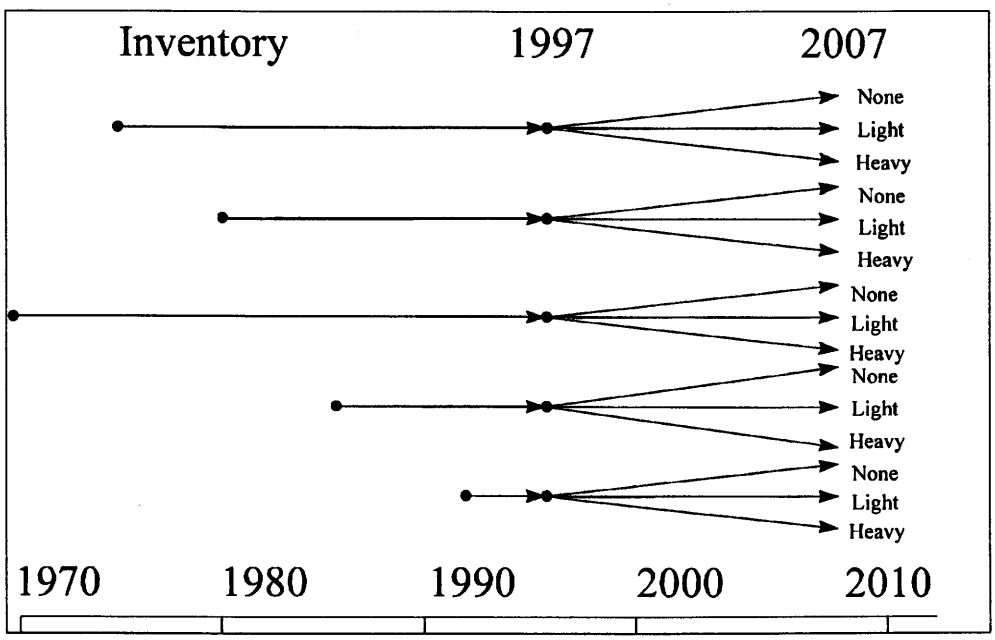

Figure 2.—Process of simulations: inventories for each stand are grown forward to 1997; if silvicultural prescriptions are to be simulated, that happens next; finally the three 10-year simulation scenarios (none, light, and heavy outbreak) ending in 2007 are executed.

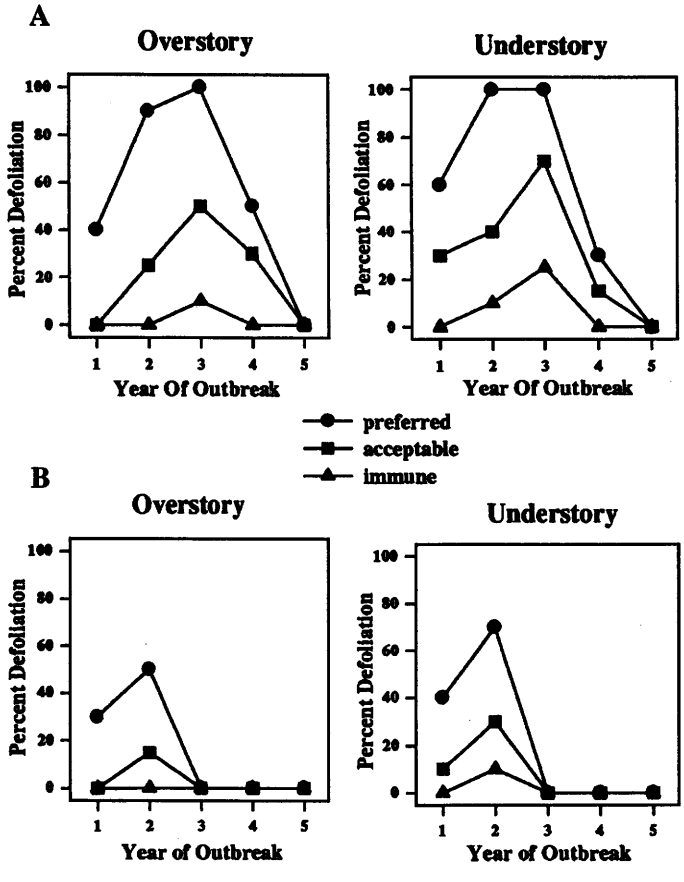

Figure 3.—A. Heavy outbreak defoliation intensities in the overstory and understory for 5 years. Gypsy moth host tree species determines feeding preference class. Each simulation repeats this 5-year sequence twice over the 10-year simulation. B. Light outbreak defoliation intensities.

slopes on southeast to northwest aspects, and upper slopes on the northeast aspect. The majority of this area is densely stocked.

Analysis was based upon compartment examination data that are routinely collected by Wayne National Forest personnel. Individual tree data were collected on 10 BAF variable-radius plots. The forest types used in the analysis were [1] black oak—scarlet oak—hickory; [2] white oak; [3] yellow-poplar—white oak group—red oak group; and [4] mixed oak. Chestnut oak forest type and northern red oak forest type were not used because these types occurred on too few stands.

To assess the possible damage caused by future gypsy moth outbreaks in the Dorr Run Area we used a sample of 38 stands that were well distributed across six compartments and the four principal oak-hickory forest types that the gypsy moth is known to find most preferable, representing both the spatial mixture and the ecological range of potential impacts. The available inventory was categorize to compartment and forest type; a balanced random sample was chosen from within this stratification. We investigated potential losses by producing a series of stand growth and defoliation scenarios using the Gypsy Moth Stand-Damage Model (Colbert and Racin 1995, Colbert and Sheehan 1995). First, the model was used to grow all tree data from previous inventories forward through 1996 to represent the current condition of each stand. Growth scenarios, each a 10-year projection, were then constructed to estimate potential tree mortality (Fig. 2). Simulations were run with and without defoliation and following selected silvicultural activities simulated to take

in 1997. Figure 3 shows the heavy and light defoliation scenarios that were used in this analysis. These scenarios are the same duration and intensity as those developed for loss assessments in the National Gypsy Moth Environmental Impact Statement (Northeastern Area, State and Private Forestry 1995). Each decade simulation consisted of two 5-year outbreak cycles. The amount of defoliation to a particular tree depended upon its location in the stand canopy and the feeding preference of gypsy moth to that tree species (Liebhold et al. 1995).

Table 1.—Stumpage price in 1997 dollars per thousand board-feet (Source: 1995 Ironton R. D. sales, Timber Sales Staff, Wayne National Forest).

Common name	Scientific name	Price
		Dollars
White Ash	*Fraxinus americana* L.	240.00
Black Walnut	*Juglans nigra* L.	240.00
Yellow Poplar	*Liriodendron tulipifera* L.	60.00
Black Cherry	*Prunus serotina* Ehrh.	240.00
White Oak	*Quercus alba* L.	150.00
Scarlet Oak	*Quercus coccinea* Muenchh.	55.00
Chestnut Oak	*Quercus prinus* L.	55.00
Red Oak	*Quercus rubra* L.	195.00
Black Oak	*Quercus velutina* Lam.	195.00

Under each alternative a no-defoliation scenario was used as the control to base the effects of defoliation upon each variable, summarized to the stand level in 2007, at the end of the simulation. Stem count, relative density (Stout and Nyland 1986), basal area, board-foot volume, and net present value were used to characterize each stand. To calculate the potential dollar losses, local stumpage values ($/MBF) for the most commercially important species were determined (Table 1). All other species were set to $35.00/MBF as the default 1997 value. Net present values (1997) for final 2007 stumpages were calculated using a 5 percent discount rate.

The two silvicultural alternatives chosen for this study consist of prescribing three parameters, the second of which depends upon the stands relative density in 1997. First, all stems less than 6 inches are removed. Second, the residual stand density is set either to 60 percent or to 80 percent of full stocking, if the 1997 relative density is above 70 percent or 90 percent, respectively. Finally, the removals are weighted toward higher removal of smaller stems, 20 percent more is removed from the smallest diameter class than is removed from the largest diameter class present and this weight is scaled down linearly from the smallest to the largest diameter class.

The GypsES Decision Support System is an expert system shell and GIS to support management of gypsy moth problems (Gottschalk et al. 1996). Besides providing access to the tree data organized in an efficiently linked database, this system provides access to stand level information, which links the models directly to the database for setting initial conditions and providing an efficient means to compile the 18 tables from each simulation of each stand for each treatment into compact files for further analysis. The menu-based selection of particular stands and system's ability to recall the structure and format designations for simulation outputs made the operation of repeated simulations much more efficient than the process would have been otherwise.

The entries provided in the summary tables were obtained as follows: first the totals across all trees in each stand simulation were calculated, then the loss in each stand was calculated as the difference between the outbreak and the no-outbreak totals. For example, the basal area is calculated and summed for all trees in each stand for each of the three simulations (no defoliation, heavy outbreak, and light outbreak), then the difference is calculated on a stand-by-stand basis (heavy minus none and light minus none), and finally the mean of these differences in basal area for each stand is presented here, as the average loss in basal area. The range of variability among the stands used in this study is also reported.

RESULTS

Three sets of alternative management scenarios were investigated: no action, light presalvage thinning to 80 percent relative stocking, and presalvage thinning to 60 percent relative stocking (B-line). The no-action alternative serves both as one alternative and as the basis for comparing effectiveness of alternate possible actions.

No Action Alternative

To ascertain how silvicultural manipulations aimed to reduce potential gypsy moth impacts could improve these stands, base-line information on the range of potential impacts is needed. The first step in this process is to simulate growth of the inventory data to the current year (1997) to provide equivalent starting points. Then each stand was projected forward from 1997 to 2007 three times: a) to estimate stand conditions in the absence of gypsy moth; b) to assess impacts of defoliation under the light outbreak scenario; and c) under the heavy outbreak scenario. These data provide the no-action alternative and bounds for assessing the effectiveness of silvicultural alternatives. By summarizing the means and extremes across these stands, we obtain the most probable boundary conditions and the basis for measuring management effects. Table 2 provides estimates of these conditions on a per acre basis.

First note that these ranges are assessed independently within each column. That is, the stand that has the smallest number of trees lost may not be the same stand that has the smallest stocking reduction, and both of these may be different from the stand with the smallest basal area loss. In this and following tables, the losses provided are due to defoliation of the residual stand following treatment and do

Table 2.—Future stand conditions following heavy and light outbreaks—losses calculated from the results of simulations on 38 stands.

Stand category	Trees lost	Stocking reduction	Basal area lost	Volume lost
	Trees/acre	Percentage	ft²/acre	MBF/acre
		Heavy Outbreak		
Average	55.9	45.0	52.0	3.0
Best	[44.0]	19.0	19.5	0.7
Worst	383.0	79.0	84.1	5.1
		Light Outbreak		
Average	19.5	6.8	7.7	0.4
Best	0.0	1.0	1.5	0.0
Worst	179.0	21.0	22.3	1.5

Note: the brackets indicate a net gain rather than a loss.

Table 3.—Losses due to defoliation calculated for the 24 stands that qualify for both presalvage treatments (no presalvage thinning done).

Stand category	— Trees lost — All	0-6	6+	Stocking reduction	Basal area lost	Volume lost
	Trees/acre			Percentage	ft²/acre	MBF/acre
				Heavy Outbreak		
Average	69.1	13.6	55.5	55.4	62.2	3.8
Best	[22.0]	[64.0]	27.0	35.0	41.2	2.4
Worst	383.0	345.0	93.0	79.0	84.1	5.1
				Light Outbreak		
Average	21.4	10.6	10.8	9.3	10.4	0.6
Best	2.0	[11.0]	1.0	2.0	2.9	0.1
Worst	179.0	177.0	24.0	21.0	22.3	1.5

Note: the brackets indicate a net gain rather than a loss.

not include the treatments themselves. These estimates provide a view of the possible range of outcomes in susceptible stands as gypsy moth becomes established in the Dorr Run area. Losses of basal area can be expected to range from a low of 20 percent to more than 80 percent in stands heavily dominated by preferred host species, with average losses per acre over the entire area expected to be above 50 square feet of basal area and nearly 3,000 board-feet per acre.

Regeneration was included in these simulations. In the "Trees Lost" column, the loss of trees includes the compensation by ingrowth predictions. Understanding these differences requires some careful interpretation and detailed review however, because replacement trees are often a different species from those lost. Because defoliation and any subsequent tree mortality will inhibit both mast production and stump sprouting, new trees will likely be species not favored by the gypsy moth or species that produce light seeds that can be carried into a stand from surrounding areas. Even as the number of trees increases in a few stands, these new trees are very small and represent natural regeneration. Although tree counts may decline minimally or increase slightly, stocking (a measure of the trees ability to fully occupy the growing space) is reduced significantly. Closely paralleling stocking, the changes in basal area better reflect the losses of the larger trees. The changes in volume per acre (measured here in thousands of board-feet [MBF]) indicate that tree values are significant. Based on market prices as of December 1996, losses may run as high as $381.00/acre from severe outbreaks with an average loss of $245.10/acre.

To permit direct contrasts between silvicultural prescriptions and no management, we again summarize only stands that will qualify for all management prescriptions (Table 3). To qualify for thinning to 80 percent relative stocking, a stand is required to be at least 90 percent fully stocked in 1997. In the Dorr Run Area, 24 stands meet that criteria. These more heavily stocked stands also tend to show higher average losses.

To assist in review of these data, we provide the mean and range for trees lost in three classes: [1] total stems count (all) [2] the small trees (less than 6 inches), and [3] large trees (6 inches and greater). Comparing Tables 2 and 3, one can see that the stands with lower relative stocking levels (the 14 stands dropped) would be affected less by defoliation. In these heavily stocked stands, expected losses will be 20 percent higher than the general average and volume losses are expected to increase more than 25 percent to nearly 4,000 board-feet per acre. This demonstrates that the potential benefits of silvicultural treatment can be substantial.

Presalvage Treatment Alternatives

Silvicultural treatment, in which the most susceptible trees were removed, provides growing space to permit the residual stand to become healthier and more resistant to defoliation as growth rates increase. In the two presalvage treatments considered in this analysis, we assumed that the trees to be removed would be those most likely to be killed by gypsy moth defoliation (Gottschalk 1993, Gottschalk and MacFarlane 1992). Gypsy moth tends to kill higher proportions of the low-vigor trees. Although tree vigor ratings have not been done in these particular stands, established estimates of tree vigor were used from similar stands in Pennsylvania where the rate of tree mortality was measured as the gypsy moth established itself over the past two decades (Gottschalk et al. In press). These stands were comparable in species composition, stand density, and site conditions, and it is expected that similar patterns of defoliation and losses will occur in the coming decade in the

Table 4.—Losses due to gypsy moth defoliation following presalvage thinning to the 80-percent line for 24 stands that will be at least 90 percent of fully stocked in 1997.

Stand category	—Trees lost— All	0-6	6+	Stocking reduction	Basal area lost	Volume lost
	Trees/acre			Percentage	ft²/acre	MBF/acre
				Heavy Outbreak		
Average	[60.1]	[94.2]	34.1	38.0	43.5	1.5
Best	[106.1]	[137.0]	19.0	30.0	34.9	2.9
Worst	[26.0]	[57.0]	62.0	53.0	56.4	3.6
	Light Outbreak					
Average	[1.6]	[2.6]	1.0	2.8	3.4	0.3
Best	[10.0]	[13.0]	[1.0]	1.0	2.0	0.1
Worst	1.0	1.0	3.0	5.0	5.7	0.5

Note: the brackets indicate a net gain rather than a loss.

Dorr Run area. Vigor is rated using a three class system (Gottschalk and MacFarlane 1992) that provides significant differences in mortality prediction power by species groupings, canopy position, and defoliation intensity (Gottschalk et al. In press, Colbert et al. In press). Tree vigor rating was the single strongest predictive variable, followed by canopy position of a tree, while species group and defoliation showed nearly equal but slightly less significant predictive power.

We next considered minimal intervention, removing only the most vulnerable trees from the most heavily stocked stands. To make that assessment, we started with the same 1997 conditions and interposed the removal of those trees that are most likely to be killed by future gypsy moth outbreaks (trees with dieback or poor vigor). Of the 38 sample stands, 24 were sufficiently overstocked (relative density greater than 90 percent of fully stocked, Stout and Nyland 1986) to be considered for minimal removals to the 80-percent line. Following the removal of those trees, we again grew the stands forward 10 years to look for changes in the descriptive measures provided above. Three projections were run over the same 10-year period following simulated presalvage entries in 1997 (Table 4).

The stem count, basal area, and volume data used to generate Table 4 were also used to generate the "80%" box-and-whisker plots in Figures 4-6. The most obvious effect is that removals done as presalvage thinning will not only save residual stocking, but also will increase the number of trees significantly. Many of the new trees will be of the same species as the trees removed because the root systems of live cut trees will allow for stump sprouting to occur. Note that this minimal presalvage harvest also saves, on average, 18.7 ft²/acre (62.2-43.5) of basal area and increases relative stocking by 17.4 percent. These translate into a relative increase of 30 percent over the no action alternative. That is, there can be an expected saving of 30 percent of the residual basal area that would otherwise be lost due to severe gypsy moth defoliation. It should be noted that these differences do not consider those trees removed during the thinning operations.

The second option considered was a heavier presalvage cut to remove more low-vigor trees, recover more of the projected loss, and have a healthier (faster growing) residual stand. In these scenarios, we considered presalvage thinning to a level that would maximize available growing space while maintaining recommended stocking levels (the B-line or 60 percent relative stocking). Of the 38 stands used in the analysis, 31 qualified for such management in 1997. Following this simulated removal in 1997, we projected stand growth through the 1998-2007 decade and again compared the differences between the moderate and heavy outbreak scenarios and the no-outbreak scenario (Table 5).

This level of presalvage thinning further reduces the overall impact of gypsy moth. It should be noted that the assumption here has not been to reduce the severity of defoliation, but rather to reduce the expected level of tree mortality by removing trees expected to die as a result of a gypsy moth outbreak. Preventative treatments offer substantial economic savings and improve the overall health of the residual forest. Enhanced by increased growing space and nutrient availability, both regeneration and residual trees respond with improved growth and vigor. Furthermore, these conditions improve the tree's chances to recover from defoliation with minimal damage, as is demonstrated in the heavy outbreak scenarios when we compare the average stocking among these three tables. Loss in stocking drops from a 45 percent loss with no management, to 38 percent when lightly thinned, and to a 27.6 percent loss when these forest

Table 5.—Losses due to gypsy moth defoliation following presalvage thinning to the 60-percent line for the 31 stands that will be at least 70 percent fully stocked in 1997.

Stand category	Trees lost	Stocking reduction	Basal area lost	Volume lost
	Trees/acre	Percentage	ft²/acre	MBF/acre
		Heavy Outbreak		
Average	[29.5]	27.6	32.4	2.1
Best	[80.0]	15.0	22.0	1.5
Worst	14.0	39.0	41.3	2.7
		Light Outbreak		
Average	2.7	1.5	1.9	0.1
Best	[4.0]	1.0	1.1	0.0
Worst	7.0	3.0	3.8	0.3

Note: the brackets indicate a net gain rather than a loss.

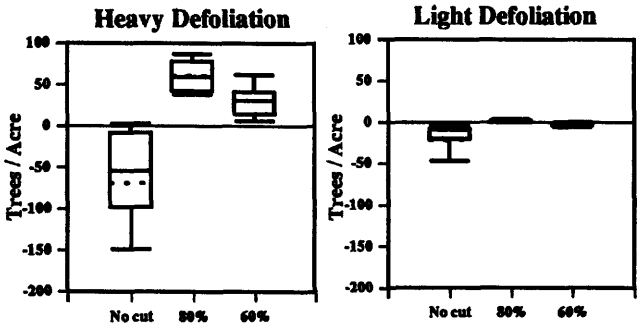

Figure 4.—Tukey box plots of predicted tree count differences in 2007 under the three alternative silvicultural practices. The whiskers are at 5 and 95 percent of the data range while the boxes span the 25 to 75 percent range with a solid 50th percentile and a dashed mean line.

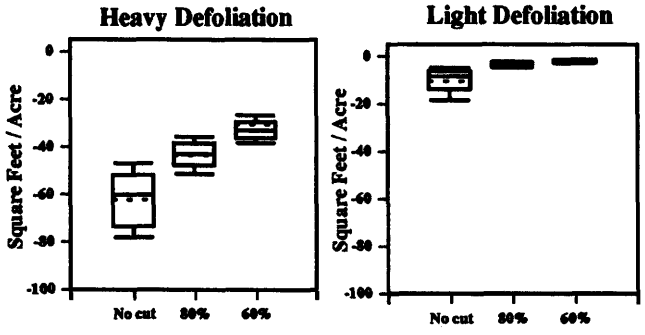

Figure 5.—Tukey box plots of basal area differences in 2007 under the three alternative silvicultural practices.

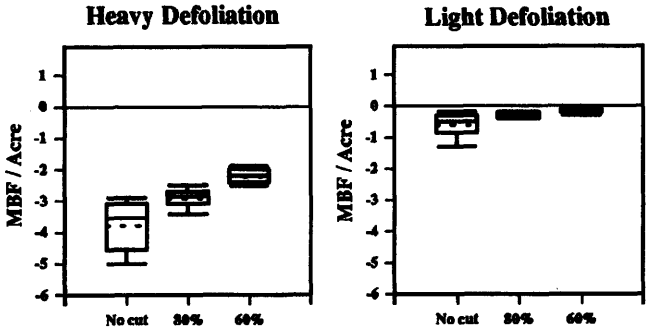

Figure 6.—Tukey box plots of standing volume differences in 2007 under the three alternative silvicultural practices.

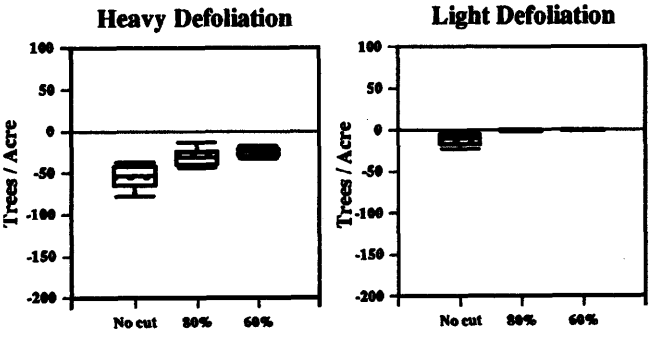

Figure 7.—Tukey box plots of predicted large (> 6 in.) tree count differences in 2007 under the three alternative silvicultural practices.

management practices are used to remove the most vulnerable trees. The end result could almost double the amount of healthy forest canopy in the average stand. To permit direct comparisons with Tables 3 and 4, we again summarize just the 24 heaviest stocked stands after cutting to the B line (Table 6).

Note that basal area and volume losses increase only slightly over the values in Table 5. Contrasting these averages with those of Tables 3 and 4 show that increased intensity of presalvage thinning will increase the savings in the residual stands. Basal area losses are reduced by 30 percent under light thinning and by 47 percent under this B-line thinning. Throughout these analyses we have concentrated on the standing timber and the residual stands, not considering the revenue generated nor any other value estimates for timber removed during these presalvage thinnings. The data used to generate Table 6 also were used to generate the Tukey box-and-whisker plots labeled "60%" in Figures 4-6.

We examined these results using analysis of variance techniques to explore variation among the compartments and forest types under consideration and found no significant differences among compartments. Thus, we conclude that these results can be applied across the area and that they represent the range of expected future impacts that gypsy moth will cause as it becomes established in the Dorr Run Area.

Table 6—Losses due to gypsy moth defoliation following presalvage thinning to the 60-percent line for the 24 stands that will be at least 90 percent fully stocked in 1997.

Stand category	— Trees lost — All	0-6	6+	Stocking reduction	Basal area lost	Volume lost
	Trees/acre			Percentage	ft²/acre	MBF/acre
				Heavy Outbreak		
Average	[30.2]	[55.5]	25.3	28.8	33.0	2.2
Best	[80.0]	[103.0]	15.0	22.0	26.6	1.9
Worst	[3.0]	[21.0]	45.0	39.0	41.3	2.7
				Light Outbreak		
Average	2.8	2.2	0.6	1.7	2.1	0.2
Best	[1.0]	[1.0]	[1.0]	1.0	1.1	0.1
Worst	7.0	6.0	2.0	3.0	3.8	0.3

Note: the brackets indicate a net gain rather than a loss.

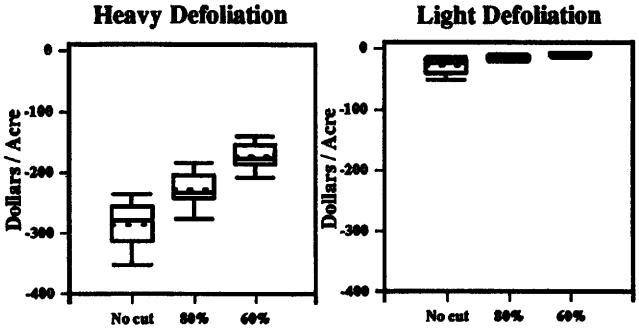

Figure 8.—Tukey box plots of volume dollar differences in 2007 (discounted to 1997 using a 5 percent rate) under the three alternative silvicultural practices.

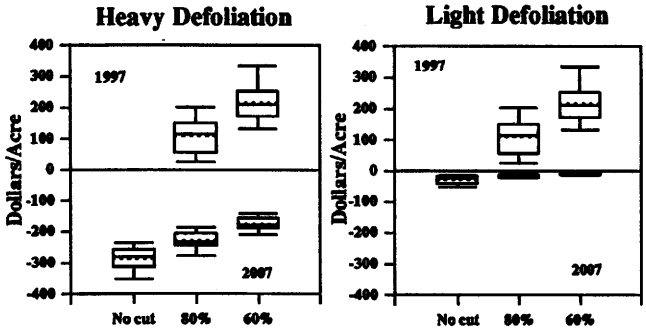

Figure 9.—Tukey box plots of present (1997) value of volume dollar differences in 2007 under the three alternative silvicultural practices, with the dollar value of the trees removed in 1997.

Ingrowth during the decade following silvicultural entry is confounding the ability to see drops in stem counts (Fig. 4). Using only trees greater than 6 inches the effect of defoliation on larger trees is apparent (Fig. 7). By comparing Figures 4 and 7, three things are made more evident: predicted ingrowth will be substantial, even in the "No cut" stands due to losses in the overstory; the range of variation in overstory stem count losses is much less than the variability in regeneration response; and silvicultural intervention will produce substantial advanced regeneration in front of the expected outbreak. Coupling these potential regeneration changes with expected basal area and volume changes in the overstory and the expected variation in average defoliation among stands following an outbreak, one can expect the losses to be reduced significantly through silvicultural intervention as selection of the highest vigor and least susceptible trees is made in the residual stands.

Dollar values of standing timber in 2007 can be viewed in current 1997 dollars by applying a 5 percent discount rate to arrive at a net present value. This provides a consistent measure for comparing current management alternatives and future stand conditions. Figure 8 shows the changes in

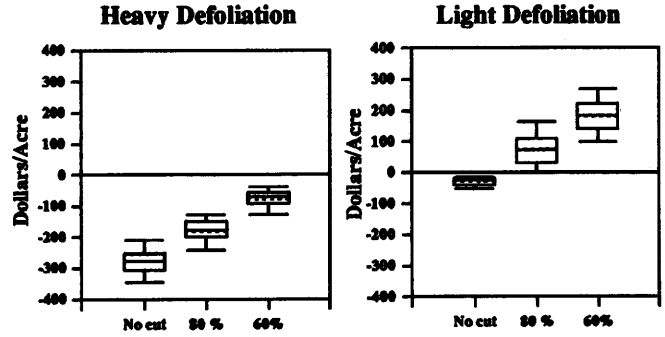

Figure 10.—Tukey box plots of net effects—sum of net present value (1997) of stands in 2007 and removal in 1997 on a stand-by-stand basis under the three alternative silvicultural practices.

the range of dollar values under the three management alternatives. Note that significant reductions in dollar losses are achieved under the minimal removal alternative, and further significant reductions are attained by normal B-line presalvage thinning under heavy defoliation only. These reductions are to the residual standing crop, and do not take into account the value of the 1997 removals (Fig. 9). Combining the dollar gains from sales with the losses, one sees the net value of management in Figure 10. Note that minimal presalvage thinning will nearly cut the losses from heavy defoliation in half, and B-line thinning will reduce losses by more than 75 percent.

CONCLUSIONS

The purpose of this study was to provide the most current management tools for silviculturists on the Wayne National Forest as they attempt to deal with the impending outbreaks of gypsy moth in southeastern Ohio. The cooperative effort provided the Wayne National Forest with the latest modelling tools and methodology integrated within a decision support shell, GypsES, that further provided the GIS tools and database resource facilities. Stand-Damage Model simulations indicate that substantial savings can be made through silvicultural management applications and that the gypsy moth can be expected to cause greater losses in the absence of management. This work provided a demonstration of management application capabilities of the models and follow-up tests done cooperatively over the coming decade will provide further examination of these working hypotheses. The stumpage prices used in this analysis are less than those in 1997 in West Virginia and Pennsylvania for these species under similar site indices. Thus, the predicted dollar losses per acre are conservative estimates, given the potential mortality. Recent presalvage and salvage treatments on the George Washington and Monongahela National Forests have shown success in providing healthy residual stands of ample productivity and were found to be profitable to local purchasers.

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Communicating Old-Growth Forest Management on the Allegheny National Forest

Brad Nelson[1], Chris Nowak[2], Scott Reitz[1], Dave deCalesta[2], and Steve Wingate[1]

Abstract.—Successful communication of old-growth management, including the role of silviculture, is achieved by integrating as a working whole the topics addressed in this workshop. We have used research, technology transfer and adaptive management to achieve this integration on the Allegheny National Forest. Program success depends on scientists and practitioners working together. Scientists spend more time in joint technology transfer activities and helping practitioners implement operational-level trials of new silviculture, including co-development of inventory and monitoring plans. Practitioners too have increased technology transfer responsibilities. Practitioners must think more like researchers, conceiving and applying innovative management but also developing ways to monitor the effects of those treatments.

INTRODUCTION

Successful communication of the role of silviculture in old-growth forest management is achieved by integrating, as a working whole, the topics outlined in this meeting's agenda: policy, inventory and monitoring, research, demonstration, education, and partnerships. To achieve this integration in managing old-growth forests on the Allegheny National Forest (ANF) we have:

(1) listened to the public to understand their values and needs,
(2) implemented new research to answer questions,
(3) used adaptive management to learn as we go,
(4) led discussions and field trips to reach agreement on policies,
(5) spread the word to increase knowledge and understanding of old-growth forests, and
(6) welcomed partners to join us in developing a better understanding of old-growth.

Conservation of biological diversity has become an important focus of forest management (Society of American Foresters 1991). Providing all forest seres across the landscape from early-successional through old-growth is one approach to achieving this goal (Harris 1984; Hunter 1989; Oliver and Larson 1996). In Pennsylvania, recent efforts to promote the conservation of biodiversity have called for the protection and enhancement of old-growth forests (McGuinness 1995; Rooney 1995).

Most eastern forests are dominated by early to mid-successional communities. Only about one-half of one percent of Pennsylvania's forests are old-growth (Smith 1989). Interest in preserving existing old-growth, finding new remnants, and developing old-growth from younger forests is growing in the Northeast.

The challenges of communicating old-growth forest management are many:

-LISTENING - Practitioners and researchers must understand the values (ecological, social, visual, and spiritual) the public associates with eastern old-growth.

-UNANSWERED QUESTIONS - Researchers must investigate the ecology of old-growth including studies of structure, functions and processes associated with old-growth forests and convey this information to practitioners and the public.

-LEARNING AS WE GO - Researchers and practitioners should employ adaptive management strategies to restore old-growth characteristics and monitor succession.

-GETTING EVERYONE ON THE SAME PAGE - Researchers, managers, policy makers, and the public must develop a common understanding and reach agreement on old-growth policy.

-SPREADING THE WORD - Education is a continuous process. As researchers and practitioners learn more about eastern old-growth, we should take every opportunity to convey this to the public.

-JOINING IN THE FUN - As interest in eastern old-growth grows, opportunities to develop partnerships for research, technology transfer, and adaptive management will increase.

This paper describes how communication between practitioners, research scientists, and the public have aided the development and understanding of old-growth management on the Allegheny National Forest.

LISTENING

In 1986 when we began implementing the Forest Plan we designated old-growth on a project-by-project basis. For example, if we were proposing a timber sale in an area, we would designate about five percent of the area as old-growth as specified in the Forest Plan. The public questioned our approach, stating that it was rather piecemeal and didn't clearly demonstrate what old-growth values we were trying to promote.

In response to these comments, an interdisciplinary team was formed to evaluate old-growth values on a landscape scale. The result was a landscape approach to providing old-growth values that connected the large forested parcels with continuous canopy corridors. These large, relatively unfragmented parcels include the 10,000 acre Hickory Creek

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LANDSCAPE CORRIDOR FRAMEWORK

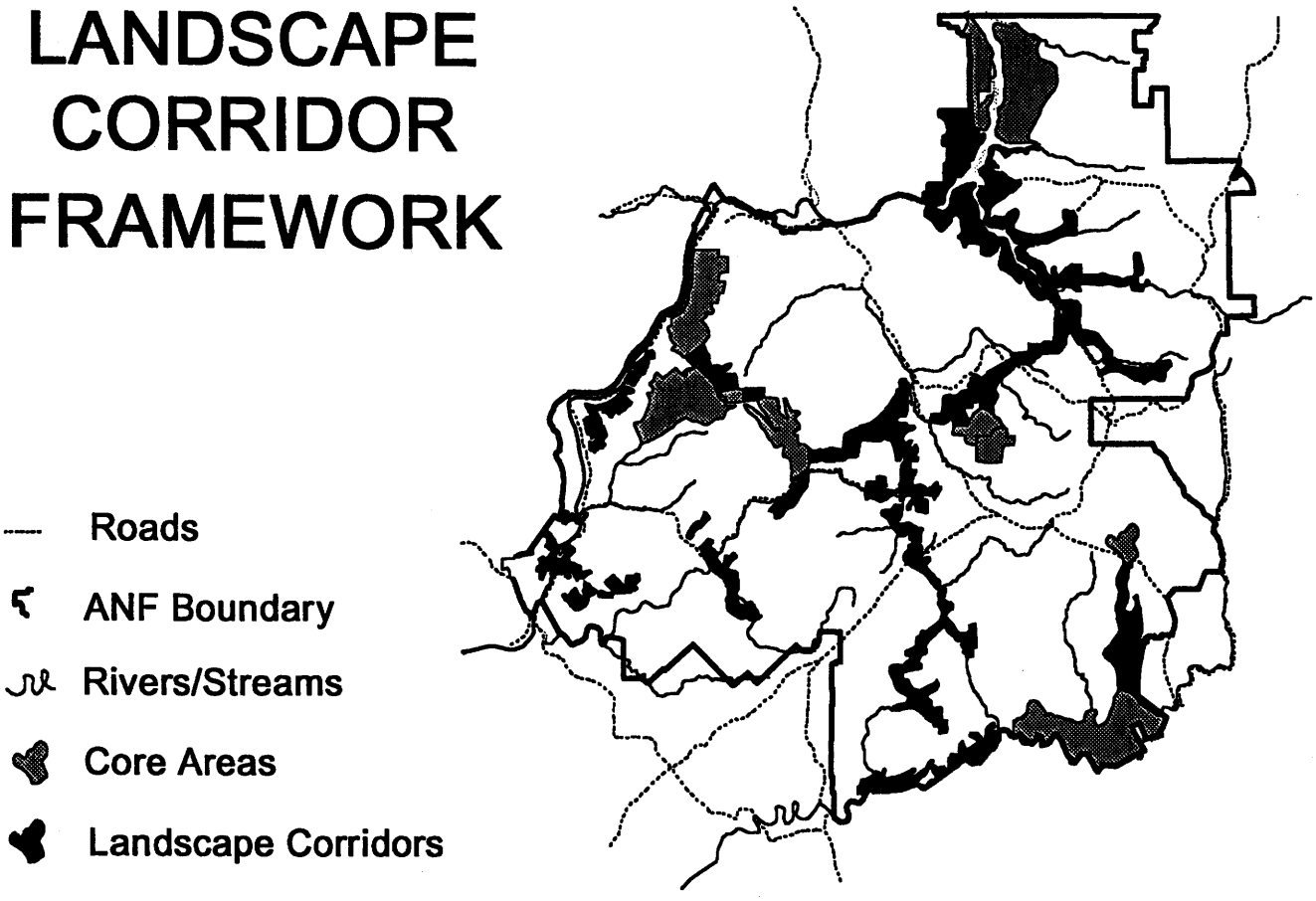

Figure 1.—Landscape corridor and core areas designated for late-successional and old-growth forests and related values on the Allegheny National Forest.

Wilderness, 9,000 acre Tracey Ridge National Recreation Area, 3,000 acre Cornplanter National Recreation Area, 7,400 acre Allegheny Front National Recreation Area, 4,100 acre Tionesta Scenic and Research Natural Areas, 3,400 acre Clarion River area, 1,300 acre Minister Valley area, and 1,400 acre Brush Hollow area. These core areas are connected by 82,000 acres of corridors (Fig. 1).

Four primary objectives for the corridor were identified by the team: connectivity, late successional/old growth habitat, riparian values, and social and amenity values (Allegheny National Forest 1995). The connectivity objective is intended to facilitate the movement of less mobile species such as amphibians, reptiles, and small mammals so they can leave areas of disturbance that do not fully meet their habitat needs and repopulate nearby areas that are recovering from past disturbance; enhance habitat for forest interior neotropical migratory songbirds by providing large blocks of contiguous forest; and facilitate genetic flow between metapopulations of less mobile species, including trees. The late successional/old-growth forest habitat objective is intended to provide habitat to meet the needs of threatened, endangered, and sensitive species; provide habitat for species requiring isolation from major human activities, species that use cavities, and species that use large woody debris; and promote ecological processes (energy flows, nutrient cycles, hydrologic cycles) that develop in late successional forests. The riparian objective is intended to complement on-going ANF initiatives to improve fisheries habitat by developing a stable source of large woody debris for some streams; and complement the on-going ANF initiatives to maintain or improve water quality and reduce sedimentation through protection of riparian areas. The social and amenity objective is intended to maintain and enhance visual quality of the forest, especially in sensitive viewsheds; and maintain and enhance recreational and amenity values associated with late-successional and old-growth forests.

A brochure and table-top display were developed to solicit additional public comments on the landscape corridor approach. Presentations and/or displays were given at more than 18 conferences, workshops, and meetings and 36 individuals responded in writing. With this input we designed the landscape corridor to meet a variety of objectives, functions, and values. While old-growth values are featured in the corridor, other objectives may be more important in some areas than in others (Allegheny National Forest 1995).

UNANSWERED QUESTIONS (RESEARCH)

Over the course of the last decade, we have learned of many unanswered questions for old-growth management on the ANF. We have also learned that much research has been conducted in ecology and silviculture, all the way back to the 1920s, that is useful in old-growth management today. Research answers and needs can be organized into three areas: ecosystem dynamics, human dimensions, and silviculture and resource management. We present a brief history and the questions yet to be answered in each.

Ecosystem Dynamics

We need research in ecosystem dynamics to gain insights into ecological states and processes of old-growth. Our goal is to learn about ecological capabilities so that desired future conditions for stands and landscapes can be developed, and management programs can be implemented that may include silviculture to sustainably promote old-growth values.

Ecological research extends back to the late 1920s with the work of Hough, Lutz, Morey and others. At that time, there were still tens of thousands of acres of virgin forest within the 700,000 acre ANF proclamation boundary. Scientists studied many of these forest as they were being cut. In one such study, Hough and a crew of over 20 from the Civilian Conservation Corps aged 100s of trees across a 7,000 acre hemlock-hardwood old-growth remnant as it was being cut (Hough and Forbes 1943).

Today, less than 5,000 acres of remnant old-growth exists on the ANF, most of that in the 4,100 acre Tionesta Scenic and Research Natural Area. This remnant and others, including Hearts Content, a 120 acre white pine-hemlock-hardwood remnant, have been valuable for studying old-growth. Over 50 research papers have been written on the Tionesta and Hearts Content areas, with 15 on-going studies across both areas today. A key to our old-growth management program has been the availability of the Tionesta and other remnants, both for education and for research.

Studies in the past focused on the state of old-growth with detailed descriptions of tree size and age distributions and species composition. There were few function- or process-level studies, with the exceptions being Hough's studies of regeneration, succession, and soil-site-species relations. Landscape perspectives on old-growth were anecdotal.

We need more basic information on ANF old-growth, including more information on states (e.g., coarse woody debris, wildlife communities, fungi, and invertebrates). Future research should be focused on understanding functions and processes. We need studies in disturbance regimes, forest stand dynamics, soil development, biogeochemical cycling, and species-site relations. While we have current studies in many of these areas, we need many more, and we need them soon.

Human Dimensions

Research defines the values people derive from old-growth and determines whether management can culture stand and landscape conditions to provide those values. We have learned some of this through the National Environmental Policy Act process and our experiences in information and technology transfer, but much could be learned with formal social study.

Silviculture and Resource Management

Silviculture is becoming recognized as having a prominent role in restoring and sustainably maintaining old-growth ecosystems. For the ANF, indepth silviculture knowledge is available. Many of the same scientists who described the old-growth forest during the 1920's and 1930's, as cited above, also conducted silviculture research. Preliminary silviculture guides were developed by Hough and others in the 1940's and 1950's (Hough 1953, 1959; Hough and Forbes 1943). These guides have been substantially revised and expanded (Marquis et al. 1992; Marquis 1994). While silvicultural techniques and methods were chiefly developed for timber values, they can be modified to achieve old-growth values. New silvicultural practices can be developed specifically for old-growth. We are presently using both old and new silviculture to restore some old-growth values to the ANF.

LEARNING AS WE GO (ADAPTIVE MANAGEMENT)

We have implemented some of our knowledge of ecosystem dynamics, human dimensions, and silviculture into operational-level forest management using an adaptive management approach. We have released subordinate conifers in maturing hardwood forests. We have underplanted conifers in partial cut hardwood stands. And we have maintained coarse woody debris during tornado salvage and enhanced coarse woody debris during partial cutting. We have demonstrated these practices, and related them to desired future conditions to generate reaction and feedback from stakeholders. We are in the process of analyzing the results of these interactions and will, if necessary, refine or change management practices so as to better achieve the desired future conditions.

All of these treatments—conifer planting and release and proactive management of coarse woody debris by leaving or creating large dead wood structures—took place in the landscape corridor (see previous section). The corridor and its core areas are the key to ANF old-growth. The core areas include both old-growth (Tionesta and Heart's Content) and unmanaged second-growth forest which will develop into old-growth in 200+ years. There are nearly 40,000 acres of core areas. The 82,000 acres of landscape corridor will be managed proactively to meet objectives, including old-growth values. We will continue to work on developing desired future conditions for this area, alter the vegetation with silviculture to accelerate attainment of these conditions, and monitor the effects of silviculture treatments in sustainably providing old-

growth values. We are exploring management buffer zones around the core areas. And in addition to the landscape corridor-core area system, small remnants of old-growth outside the corridor-core areas will continue to be preserved. In total, nearly 25-percent of the ANF is being managed for old-growth values.

Major disturbances may occur in the landscape corridor that could jeopardize some of the late-successional and old-growth values that we are striving to perpetuate. Insect and disease outbreaks of native and exotic species and cyclic windstorms, particularly tornadoes, will result in the loss of some portion of overstory trees, increasing the amount of light reaching the forest floor and increasing the amount of dead wood in the forest. If a catastrophe results in substantial tree mortality such that connectivity and late successional objectives cannot be met, restoration activities that feature silviculture such as planting and fencing to prevent overbrowsing by deer may be implemented.

GETTING EVERYONE ON THE SAME PAGE (CONSISTENT POLICY - TECHNOLOGY TRANSFER)

Multiple objectives, refined definitions, and taking a long term view at a broader scale are factors that have contributed to the complexity of the landscape corridor/old-growth concept. On the Allegheny National Forest, we have found that discussing old-growth issues in the woods gives all participants a common understanding of the complex situation and helps us reach agreement and consensus. We have spent a day with the ANF Forest Leadership Team in Tionesta Scenic and Research Natural Areas viewing and discussing the differences between late-successional forests and true old-growth, and how species composition, levels of dead wood, and wildlife use change as forests become older. We have reviewed the implementation of some of our corridor projects with many ANF employees and publics to determine if we did what we said we would do and if we achieved the results we were striving for.

SPREADING THE WORD (EDUCATION)

Perhaps it is obvious, but we should take every opportunity to share information and explain to the public our late-successional and old-growth policy. Although not always possible, we believe the best way to communicate our message is in the woods viewing old-growth first hand. Last year we led field discussions with more than a dozen groups (>200 people) to discuss old-growth on the ANF.

Discussions of succession and how old-growth characteristics develop over time have helped people understand how old growth develops. A simple distinction between late-successional forests and old-growth forests has helped us communicate the importance of time in developing old-growth values. Late-successional forests, transitional old-growth, and potential old-growth are all used to describe forests between 111 and 300 years old (111 years is used in the ANF's Forest Plan as an old-growth theshold). Forests older than 300 years are defined as true old-growth or ecological old-growth. These definitions, which follow the recommendations of Oliver and Larson (1996) and research results specific to hemlock-hardwoods by Tyrrell and Crow (1994), have been useful in discussing the temporal aspects of old-growth values and how some old-growth values accrue during the late-successional forest stage and peak during the old-growth stage. Discussion of the spatial aspects of old-growth, embodied in the landscape corridor itself, have benefitted from Mladenoff et al.'s (1993) and Lorimer and Frelich's (1994) descriptions of presettlement hemlock-hardwood landscapes in the Midwest.

JOINING IN THE FUN (PARTNERSHIPS)

Interest in eastern old-growth is growing and with that interest comes many questions that warrant investigation. Many researchers have studied a piece of the puzzle, but few opportunities to bring all the pieces together have occurred. Last summer, we brought all the researchers together who have studied various components of the Tionesta Research Natural Area. Each researcher had the opportunity to discuss his/her research and learn from the research findings of others. The result was a better and more holistic understanding of eastern old-growth and the generation of more questions that need investigation. We plan to continue these research cooperator meetings every other year.

To evaluate the success of the landscape corridor and core area concept in meeting identified objectives, a carefully designed monitoring program should be implemented. This program can include the monitoring of selected wildlife communities, plant communities, and featured habitats such as late-successional habitats and riparian areas. We recognize that no single agency could undertake all the monitoring that is needed to answer the many questions concerning landscape corridors and late-successional forests. We openly invite colleges, universities, and other partners to become actively involved in monitoring, research, and adaptive management in old-growth forest management on the ANF. To meet this end, we have taken our show on the road, soliciting scientific input from outside the Forest Service through various workshops and field tours. A workshop we ran this past spring at The Pennsylvania State University resulted in two new research projects, one on hemlock wooly adelgid and the other on watershed nitrogen dynamics, both to occur in the old-growth on the Tionesta Scenic and Research Natural Area.

IN CLOSING ...

The success of communicating old-growth policy and the role of silviculture in management of old-growth forests depends on scientists, practitioners, and the public working together. Scientists spend more time in joint technology transfer activities and helping forest managers implement operational-level trials of new forest management. Practitioners must understand the values that the public associates with old-growth forests and incorporate these values into old-growth management policies. Practitioners must continue to conceive and apply innovative management, and also develop research-like ways to

monitor the effects of those treatments. Each—scientist and practitioner—needs to spend more time helping others understand their own knowledge and experience. Synergism will occur. Policy and practice will change and our understanding of old-growth will increase, all to the benefit of the forest.

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Use of Expert Systems for Integrated Silvicultural Planning

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Abstract.—The use of silvicultural treatments in hardwood stands presents opportunities for increasing the growth and yield of quality sawtimber and enhancing the suitability of the site for use by numerous species of wildlife. Planners, loggers, and managers must consider multiple aspects of the ecosystem when making silvicultural decisions. In this paper we demonstrate an integrated expert system called FOREX and explain how it can be used to make silvicultural decisions that integrate potential growth and yield, logging technology, economics, wildlife, markets, log prices, and the time value of money.

INTRODUCTION

Owners of forested land are being challenged to meet ecosystem/landscape level goals while meeting personal and financial objectives. This challenge is further complicated by the need for integrated planning, i.e., considering all of the present and potential values and benefits available from forested ecosystems. Information on wildlife habitat, silvicultural practices, logging technology, economic and market factors, and the time value of money must be integrated when deciding how to manage forest lands. The natural process of forest establishment, growth, and development must be studied to better understand the potential values and benefits of proposed silvicultural treatments over time.

Forest ecosystems undergo a series of seral stages that lead to a climax state over time (Odum 1969; Hunter 1990). For example, many ecosystems left undisturbed undergo a series of stages because system changes are constant over time. The vegetation at each stage in the process suits different creatures and different people at different times. As the forest moves through these seral stages, wildlife comes and goes, for example, a thicket-like stand at age 30 will have few grouse and gray fox by age 60. Or a forest stand may be in the pole-timber class for 30 to 50 years as part of its 90- to 200-year rotation age. In this stage, trees of the same species kill each other in competition for light, nutrients, and water (Odum 1969). Also during this phase, many different species of wildlife occupy and use the site (DeGraaf et al. 1991) and also kill each other in a natural struggle for survival (Dasmann 1964; Odum 1969; Hobson et al. 1993; Black 1994). During this period, 30 to 50 years, many plant, tree, and wildlife species can be harvested without stopping or setting back the process.

At some point in this natural process, forests contain fewer but larger trees. These "larger" woods seem to be those that many people want to protect and/or keep constant. But nature does not stand still. In fact, goals for timber production often mimic the natural process of succession. For example, researchers have demonstrated that thinning stands can produce trees that are more valuable and faster growing than those in many unmanaged stands. It is to everyone's advantage to understand and plan for the potential products, values, and benefits that forest stands yield over time. It also is important that managers understand the economic implications of their actions and are able to evaluate the economic tradeoffs that result from alternative silvicultural treatments.

Another major concern of owners is bringing together the volumes of research information on wildlife habitat, stand management, logging technology, economic and market factors, and the impact of time when deciding how to manage their forest land. This challenge is complicated in that the vegetation and various organisms that make up a forest ecosystem survive and reproduce on a site because they have adapted to their physical environment and are able to coexist with one another. When humans disturb this balance by removing vegetation from the site or changing its species composition, the site may no longer be suitable as habitat for certain wildlife species. Managers can avoid much of this potential disruption to wildlife by maintaining the natural/original species composition of the site/stand. This may best be achieved by the use of natural regeneration following disturbance/regeneration versus regenerating the site with artificial methods that favor one species of vegetation over another (Hunter 1990).

A second complication is the lack of decisionmaking software/tools that allow for integration across disciplines. As a result, land owners usually manage their land according to personal experience. Often, the result is the continued implementation of a handful of silviculture practices that may not meet all of the owner's objectives.

We have developed an expert system called FOREX that allows integrated decisionmaking in managing of hardwood forests (LeDoux et al. 1995; 1996; LeDoux 1997). FOREX considers the potential growth and yield, products, and development of a stand over time, economic and market factors, and impacts on wildlife habitat. This system can be applied to all forest types in the Northeast, and currently considers impacts on wildlife habitat for New England forest types. Wildlife data from other forest types and regions will be incorporated into the FOREX database as they become available. In this paper we explain how FOREX can be used to evaluate the flow of potential products, values, and benefits associated with a forested stand over its life.

Description of FOREX

FOREX uses data from simulation runs from a model called MANAGE (LeDoux 1986; LeDoux et al. 1995). The user can obtain information on present net worth (PNW), optimal

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timing of thinning entry, optimal economic stand-rotation age, average diameter at breast height (dbh), volume by grade and value of the trees harvested, and, depending on the cable yarder or ground-based system used, average slope yarding or skid distance, truck class, road class, log-bucking methods, and number of thinnings desired. FOREX also provides information on the effect of harvesting treatments on wildlife habitat. Users can obtain data on the PNW, dbh, and volume required for a specific set of management objectives, and perform a sensitivity analysis that eliminates the need to sort through numerous simulations.

FOREX also can be used to project growth and volume yields, yields of individual wood products, estimate stump-to-mill logging costs, predict cash flows and discounted PNW revenues, project the suitability of habitat for wildlife, estimate optimal periods between thinnings or other silvicultural treatments. From these data, users can gauge the impact of various silvicultural treatments on wildlife and evaluate management tradeoffs such as longer rotations for wildlife versus shorter ones for fiber production.

Stand Conditions Used

For this demonstration, we used a stand from the northern red oak forest cover type. The species mix includes chestnut oak, scarlet oak, black oak, hickories, red maple, and red oak. The average site index is about 70. The stand is 30 years old and contains about 330 trees per acre that are more than 5 inches dbh; the average stand diameter is 6.37 inches dbh. The stand is on moderate to steep slopes and could be harvested by cable or ground-based systems. The site is covered with greater than 25 percent rock cover, has greater than 30 percent forest litter cover, has active seeps, loose soils and small caves, and has at least 50 ft^3/acre of dead and down material on the forest floor. The land has about 20 percent shrub cover and at least 29 percent ground cover. For this demonstration, the management block is assumed to be 300 acres in size for harvesting and wildlife purposes. We input the stand information into FOREX and conducted several consultation runs to determine the potential benefits, costs, and values associated with managing such a stand.

RESULTS

The stand was subjected to thinnings at age 60, 70, and 150, with an optimal rotation age of 160 years. An additional objective of the last thinning at age 150 was to promote advanced regeneration before final harvest. The tract was logged with both cable and ground-based systems (Table 1).

Potential Growth and Yield

The stand would yield 751.20 ft^3 of wood at age 60 with an average dbh of 9.93 inches (Table 1). Thinnings at age 90 and 150 would yield 1,752.58 and 2,132.09 ft^3 respectively, and the final harvest would yield 3,627.75 ft^3. Extending the final harvest to 200 years would yield 4,362.74 ft^3.

Potential Product Yields

At age 60, the product mix consists of a small quantity of grade 3 logs with the remainder in pulpwood (Table 1). The second and third thinnings yield more grade 1 and grade 2 volume. For example, the third thinning and final harvest have high percentages of grade 1 and grade 2 logs. The final harvest has the highest proportion of grade 1 volume because the three previous thinnings favored leaving the best crop trees for final harvest. Extending the final harvest to 200 years would yield a large proportion of grade 1 logs.

Optimal Thinning Entry and Rotation Age

FOREX can be used to estimate the optimal timing of thinning entry. For this demonstration, the optimal thinning schedule is age 60, 90, and 150 with an optimal rotation length of 160 years. The thinnings can be constrained so that they break even or generate a profit before they are considered feasible, that is, the value of the products removed must pay their way to the mills.

FOREX also projects the optimal rotation age given any prior treatment(s). In this case, the stand is thinned at age 60, and the residual stand is projected to age 90 and thinned, and the residual stand at age 90 is projected to age 150 and thinned, and the residual stand at age 150 is projected forward until it reaches the optimal rotation age of 160.

Potential Monetary Yields

FOREX also projects the cash flows and PNW for each combination of thinning entry and optimal rotation. For example, thinning at age 60 would require a subsidy of $123.98 or $105.39/acre for cable and ground-based systems, respectively. Accordingly, data on PNW and cash flow are presented for each thinning, final harvest, or extended rotations. Thinnings at age 90 and 150 are economical, yielding a PNW of $86.40 or $82.53/acre depending on the logging method used.

Management Tradeoffs

FOREX can be used to evaluate/rank alternative management tradeoffs. For example, the optimal rotation at age 160 yields a PNW of $107.65 and $118.09/acre for cable and ground-based harvests, respectively. Extending the rotation to 200 years results in a PNW value of $48.83 and $53.11/acre, for cable and ground-based systems. The tradeoff in PNW represents a reduction of about 55 percent for ground-based harvests, or a net loss of about $1.62/acre/year. Although cash flows for the extended rotation are larger than those from optimal rotations, the time value of money makes future yields worth less in PNW.

Wildlife Habitat Suitability

FOREX links actual stand attributes such as dbh, volume per acre, number of trees per acre, species mix, and other stand/site attributes with guidelines of DeGraaf et al. (1992) to generate lists of potential wildlife species that would find the

Table 1.—FOREX results by treatment for 30-year old northern red oak forest stand

Attribute	Thinning 1[a]	Thinning 2[b]	Thinning 3[b]	Final harvest	Extended rotation
Yarding distance (ft)	600	600	600	600	600
Buck type	1	1	1	1	1
Road class	3	3	3	3	3
Truck class	2	2	2	2	2
Age (years)	60	90	150	160	200
Trees (no.)	57	75	35	51	41
Avg. dbh (inches)	9.93	12.80	19.27	20.43	23.97
Volume (ft^3)	751.20	1752.58	2132.09	3627.75	4362.74
G1 (bd. ft)[c]	0	915.28	6947.64	13543.29	20652.76
G2 (bd. ft)[d]	0	601.00	161.31	402.85	127.81
G3 (bd. ft)[e]	46.67	284.46	758.93	701.66	712.17
G4 (ft^3)[f]	737.33	1320.83	650.75	987.37	813.94
PNW (dollars)[g]	-51.08	49.27	75.17	107.65	48.83
Cash flow (dollars)[g]	-123.98	290.28	2609.22	5021.73	7430.94
PNW (dollars)[h]	-43.42	86.40	82.53	118.09	53.11
Cash flow (dollars)[h]	-105.39	509.03	2864.70	5508.74	8082.38

[a]20 percent of trees/acre removed.
[b]40 percent of trees/acre removed.
[c]G1 = grade 1 volume/acre.
[d]G2 = grade 2 volume/acre.
[e]G3 = grade 3 volume/acre.
[f]G4 = pulpwood/acre.
[g]Cable systems.
[h]Ground-based systems.

site/stand suitable. For example, the 160-year-old stand would yield conditions acceptable to several species of amphibians, birds, mammals, and reptiles (Table 2). Table 3 lists the potential species that would find the site/stand suitable after harvest provided that down logs and tops are left on the site following final harvest. Table 4 shows the potential species that would find the site/stand suitable after final harvest when residual down logs and tops are removed/utilized after final harvest. Such consultation runs allow users to estimate the suitability of habitat for wildlife and gauge the impact of various silvicultural treatments on wildlife. The lists produced by FOREX were cross-validated using the HAM model (Harvey and Finley 1996).

CONSIDERATIONS FOR USERS

Integrated expert systems can be used to estimate the potential values and benefits associated with the management of eastern hardwoods over time. Managers, planners, and users can obtain detailed information on growth and yield, potential product development, logging costs, potential revenues, suitability of habitat for wildlife, impacts of silvicultural treatments on wildlife, timing of thinning entry and optimal rotation age. Generally, foresters can manage the resource for an array of products and values simultaneously, and users can evaluate economic tradeoffs that result from alternative silvicultural treatments.

Refinements in the data on wildlife, product quality, and other variables are being made, and additions to the knowledge base can be easily incorporated into the FOREX database. FOREX integrates the best information on logging cost, mill prices paid, and similar factors into a user-friendly system that can be used when planning silvicultural treatments.

It is doubtful that expert systems such as FOREX will replace the expertise available at the forest or district level as there is no substitute in the short run for a manager's knowledge of the land, hand-drawn maps, etc. Still, FOREX and other integrated expert systems can be useful in the decisionmaking process and thus contribute to improved management of the nation's forest resources.

Table 2.—Potential species for stand before final harvest

Redback salamander *(Plethodon cinereus)*	Black-capped chickadee *(Parus atricapillus)*
Northern brown snake *(Storeia d. dekayi)*	Tufted titmouse *(Parus bicolor)*
Northern redbelly snake *(Storeia o. occipitomaculata)*	White-breasted nuthatch *(Sitta carolinensis)*
Northern ringneck snake *(Diadophis punctatus edwardsi)*	Brown creeper *(Certhia americana)*
Northern black racer *(Coluber c. constrictor)*	Red-eyed vireo *(Vireo olivaceus)*
Black rat snake *(Elaphe o. obosoleta)*	Blackburnian warbler *(Dendroica fusca)*
Eastern milk snake *(Lampropeltis t. triangulum)*	Scarlet tanager *(Piranga olivacea)*
Northern copperhead *(Agkistrodon contortrix mokeson)*	Brown-headed cowbird *(Molothrus ater)*
Timber rattlesnake *(Crotalus horridus)*	Purple finch *(Carpodacus purpureus)*
Sharp-shinned hawk *(Accipiter striatus)*	Carolina chickadee *(Parus carolinensis)*
Northern goshawk *(Accipiter gentilis)*	Virginia opossum *(Didelphis virginiana)*
Red-shouldered hawk *(Buteo lineatus)*	Masked shrew *(Sorex cinereus)*
Broad-winged hawk *(Buteo platypterus)*	Little brown bat *(Myotis lucifugus)*
Red-tailed hawk *(Buteo jamaicensis)*	Silver-haired bat *(Lasionycteris noctivagans)*
Great horned owl *(Bubeo virginianus)*	Big-brown bat *(Eptesicus fuscus)*
Red-bellied woodpecker *(Melanerpes carolinus)*	Northern red bat *(Lasiurus borealis)*
Yellow-bellied sapsucker *(Sphyrapicus varius)*	Gray squirrel *(Sciurus carolinensis)*
Hairy woodpecker *(Picoides villosus)*	Southern flying squirrel *(Glaucomys volans)*
Eastern wood-pewee *(Contopus virens)*	Northern flying squirrel *(Glaucomys sabrinus)*
Eastern phoebe *(Sayornis phoebe)*	Coyote *(Canis latrans)*
Blue jay *(Cyanocitta cristata)*	Black bear *(Ursus americanus)*
American crow *(Corvus brachyrhynchos)*	Red fox *(Vulpes vulpes)*
Common raven *(Corvus corax)*	White-tailed deer *(Odocoileus virginianus)*
Ruffed grouse *(Bonasa umbellus)*	

Table 3.—Potential species for stand after final harvest (down logs and tops left on site)

Northern brown snake *(Storeia d. dekayi)*	Northern ringneck snake *(Diadophis punctatus edwardsi)*
Northern black racer *(Coluber c. constrictor)*	Black rat snake *(Elaphe o. obosoleta)*
Eastern milk snake *(Lampropeltis t. triangulum)*	Timber rattlesnake *(Crotalus horridus)*
Cooper's hawk *(Accipiter cooperii)*	Golden eagle *(Aquila chrysaetos)*
Blue jay *(Cyanocitta cristata)*	American crow *(Corvus brachyrhynchos)*
Common raven *(Corvus corax)*	Ruffed grouse *(Bonasa umbellus)*
Wild turkey *(Meleagris gallopavo)*	Purple finch *(Carpodacus purpureus)*
Masked shrew *(Sorex cinereus)*	Coyote *(Canis latrans)*
Black bear *(Ursus americanus)*	Red fox *(Vulpes vulpes)*
White-tailed deer *(Odocoileus virginianus)*	

Table 4.—Potential species for stand after final harvest (down logs and tops removed)

Northern ringneck snake *(Diadophis punctatus edwardsi)*	Timber rattlesnake *(Crotalus horridus)*
Cooper's hawk *(Accipiter cooperii)*	Golden eagle *(Aquila chrysaetos)*
Blue jay *(Cyanocitta cristata)*	American crow *(Corvus brachyrhynchos)*
Common raven *(Corvus corax)*	Ruffed grouse *(Bonasa umbellus)*
Wild turkey *(Meleagris gallopavo)*	Purple finch *(Carpodacus purpureus)*
Coyote *(Canis latrans)*	Red fox *(Vulpes vulpes)*
White-tailed deer *(Odocoileus virginianus)*	

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Assessing Native American Disturbances in Mixed Oak Forests of the Allegheny Plateau

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INTRODUCTION

Although much has been written concerning the ecology and disturbance history of hemlock - white pine - northern hardwood (Nichols 1935; Braun 1950) forests of the Allegheny Plateau (Lutz 1930a; Morey 1936; Hough and Forbes 1943; Runkle 1981; Whitney 1990; Abrams and Orwig 1996) few studies have investigated the distribution and successional dynamics of oak in this region. Most witness tree studies of the Plateau cite low numbers (<4%-20%) of oak with most occurring on droughty, south facing upper slopes (Lutz 1930b; Gordon 1940; Seischab 1990; Whitney 1990; Abrams and Ruffner 1995). Both Gordon (1940) and Kuchler (1964) mapped northward extensions of oak along river valleys into southern New York. While some oak communities may represent edaphic climaxes on poor, droughty soils (Gordon 1940; Braun 1950) we believe that these northward extensions may also reflect a presence of Native American fire and or agricultural clearing (Day 1953; Meltzer and Smith 1986; DeVivo 1991). Many researchers have reported the impact of Native American disturbances on pre-European settlement forests of eastern North America (Maxwell 1910; Day 1953; Chapman et al. 1982; Pyne 1983; Patterson and Sassaman 1988; Dorney and Dorney 1989; DeVivo 1991). Nearly all reference a patchwork anthropogenic landscape resulting from the burning of forests to reduce underbrush, girdle trees, improve wildlife browse, drive game, rejuvenate fruiting species or to clear agricultural fields.

Regional pollen sequences suggest oak was present on the southern New England landscape by 10,000-9,000 years BP (Watts 1979; Webb 1981; Davis 1983). Oak-pine forests replaced spruce-pine woodlands as early as 10,500 years BP coinciding with increased charcoal abundance and a warmer, drier climate (Miller 1973; Spear and Miller 1976; Calkin and Miller 1977; Sirkin 1977). While the role of fire in the historical development of oak is widely accepted for the mixed oak region (Lorimer 1985; Abrams 1992; Abrams and Nowacki 1992; Johnson 1992) this relationship has not been fully investigated in northern hardwood forests. Clark and Royall (1995) reported a transition from northern hardwood to white pine-oak forests during a period of Iroquois occupation and agricultural clearing. In their study of New England, Patterson and Sassaman (1988) compared sedimentary charcoal and archaeological site distributions and found fires were more common on coastal sites where Native populations were greatest and their land-use practices most intensive. In addition, they noted archaeological site distributions corresponded well with areas characterized by high oak pollen percentages (Dincauze and Mulholland 1977; Patterson and Sassaman 1988).

Recent paleoecological investigations have questioned the importance and extent of Native American fire usage in oak development (cf. Russell 1983; Clark and Royall 1996). Thus, while several regional studies suggest the correlation of fire occurrence and Native occupation with oak forest distribution more research must be completed to better understand the pre-European landscape across the northeast. In this study, we wish to gain an historical perspective for the development of oak forests on the Allegheny Plateau. Our objectives include: 1) elucidating what factors existed historically to foster oak development on the landscape, 2) identify processes whether natural and/or cultural driving oak distribution, and 3) identify successional status of current oak forests on the landscape. From this information, we hope to increase our knowledge of presettlement forest conditions and develop ways we can maintain and preserve oak areas on the Allegheny Plateau.

This project integrates several disciplines to answer these questions. Palynological analysis of bog sediments will identify changes in species composition over time as well as provide charcoal evidence of previous fire events needed for radiocarbon dating. Archaeology is providing information on Native American settlement and land-use patterns while witness tree analysis and historical data help to identify pre-European settlement forest conditions. We believe a study of this scope conducted in this region will provide some compelling information concerning Native American impacts on the forest resources of the Allegheny Plateau prior to European settlement.

STUDY AREA

The region comprises the Unglaciated High Allegheny Plateau characterized by broad flat-topped ridges deeply dissected by dendritic streams (Bowman 1911; Fenneman 1938). Soils are predominantly Inceptisols formed in residuum and colluvium from Mississippian and Pennsylvanian aged sandstones and shales (Cerutti 1985; Ciolkosz et al. 1989). Hazleton-Cookport soils occur on plateau uplands while Hazleton-Gilpin-Ernest soils dominate riparian sideslopes. Both are characterized as deep, well drained to moderately well drained, sloping to moderately steep soils formed from acidic sandstone and shale. Alluvial floodplains and glacial outwash terraces consist of Wayland-Chenango-Braceville soils and are characterized as deep, very poorly drained, level to gently sloping soils formed in water deposited materials derived from acid sandstone and shale (Cerutti 1985). Climate of the region is typified as cool and humid. Average temperatures range from 20û C in the summer to -2û C in the winter months. Total annual precipitation is 109 cm with 61 cm falling during the growing season between April and September (Cerutti 1985).

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PRELIMINARY RESULTS

Archaeological Evidence

Located within the study area are 55 pre-contact and 54 post-contact archaeological sites. Several included in the Buckaloons Historic District (BHD) are regarded as the most significant archaeological sites in Pennsylvania. Prehistoric artifacts from collections coupled with evidence from extensive field projects conducted within the study area suggest human occupation for the last 12,000 years. The area was first occupied by PaleoIndians during the retreat of the Wisconsin ice sheet between 12,000 to 11,000 y BP. As the ice retreated, Paleoindians advanced northward along the Allegheny River from the southern portion of Pennsylvania and Ohio following megafauna and other game (Funk 1993). It is widely held that seasonal hunting patterns operated on a north/south directional flow along major waterways. Vegetation composition and distribution changed as the glacial margin moved northward. Tundra-like conditions existed until around 12,000 y BP when replaced by open stands of spruce and by 10,500 y BP pine-oak forests dominated the landscape coinciding with increased charcoal abundance and a warmer, drier climate. These environmental changes certainly affected human resource collection and utilization. For instance, it is believed that by this period large megafauna such as the mastodon (*Mammut americanus*) had been extirpated and other mammals such as the caribou, moose, and deer comprised much of the diet of the inhabitants. Further, the collection of acorns, walnuts, and hickory nuts is recognized as another subsistence pattern of the Early Archaic period (Munson 1986).

A scarcity of Middle Archaic (c. 8000-6000 y BP) sites and artifacts indicates either a lower population in the area or that specialists have not been able to differentiate Middle Archaic artifacts from those of adjacent periods (Stewart and Kratzer 1989; Quinn and Adovasio 1996). The pollen record for western New York indicates a decrease in pine distribution and an increase in hemlock during this period (Trubowitz 1983). Although speculative, changes in species distribution may have affected faunal migration/population patterns thus impacting human migration/population patterns. However, by the Late-Archaic (6000-3000 y BP) northern hardwood and mixed oak forests dominated the landscape. At this time Peoples of the Brewerton and Lamoka cultures (Laurentian Tradition) inhabited the region. Brewerton peoples were adapted to the upland environments while the Lamoka peoples preferred riparian areas. Both cultures are characterized with hunting, gathering, and foraging subsistence strategies. Seasonal base camps have been identified on both the upland and riparian environments. Despite information concerning cultural developments, human-environmental interactions are not presently understood.

In northwestern Pennsylvania, agriculture developed during the Woodland Period (3,000-300 y BP) and was practiced extensively by the Seneca-Iroquois nation by 1350 AD (Dennis 1993; Snow 1994). The Iroquois practiced a form of swidden agriculture in which forests were cleared and burned to create open areas (Ketchum 1864; Parker 1968). Cultigens included the sunflower (*Helianthus annuus*), maize (*Zeas mays*), squash (*Curcubita* spp.), and beans (*Phaseolus vulgaris*) (Dimmick 1994; Snow 1994). Crops were cultivated in cleared fields extending out from a central village. Fields were cultivated for several years (8-12) until crop harvests decreased enough to warrant moving the village to another streamside site (Ritchie and Funk 1979; Sykes 1980, Snow 1994). The ability to raise crops reduced the dependence on hunting and gathering. In addition, agriculture was responsible for a sharp increase in population and development of a more sedentary existence evidenced by the development of large villages (Snow 1994).

Most occupation sites occurred on river or glacial outwash terraces and ranged in size from small clan hamlets of three or five longhouses capable of supporting 15-20 persons to villages encompassing ten longhouses on 8-10 acres supporting 150-200 people (Witthoft 1965; Ritchie and Funk 1979; Snow 1994). Nearly all Iroqouis settlements were palisaded for protection (Snow 1994). These palisades consisted of large posts averaging one foot in diameter, with an upper limit of two feet (Ritchie and Funk 1979). According to the size of the village protected, constructing these defensive perimeters required a considerable amount of timber not to mention the quantity of fuelwood needed by the inhabitants.

Thus, over time, the anthropogenic landscape would resemble a mosaic pattern of (1) croplands near palisaded settlements, (2) abandoned clearings with early successional taxa, and (3) open forest stands dominated by fire adapted species such as oak and hickory (Chapman et al. 1982). Indeed, many paleoecological studies have identified a transition from later successional species to early successional species during the period of Native American burning and occupation (Chapman et al. 1982; Delcourt 1987; Clark and Royall 1995).

Witness Tree Analyses

Presettlement forest conditions were characterized by tallying corner trees from original warrant maps (1790-1820). Warrant maps represent a tract of land as surveyed at the time of first settlement (Munger 1991). Each warrant map comprises several bearings and distances linking property corners, either marked trees, posts, or stone monuments. After the tract was surveyed, a warrant map was produced illustrating the configuration of the lot, including boundary-line descriptions, property corners, whether trees or otherwise, and other outstanding geographic features such as streams, mountain peaks, or "Indian" paths (Abrams and Ruffner 1995). For this study, individual warrants and their corresponding witness corners were overlayed on USGS 7.5- min. quadrangle maps or identified on previously delineated boundary lines on USFS 7.5-min. quadrangle topographic maps. These connected drafts provided the main source for tallying the corner trees by species and physiographic landform (e.g. stream valley, north cove, plateau top, etc.).

Witness tree-topographic relationships were examined using contingency table analysis, a method which tests for

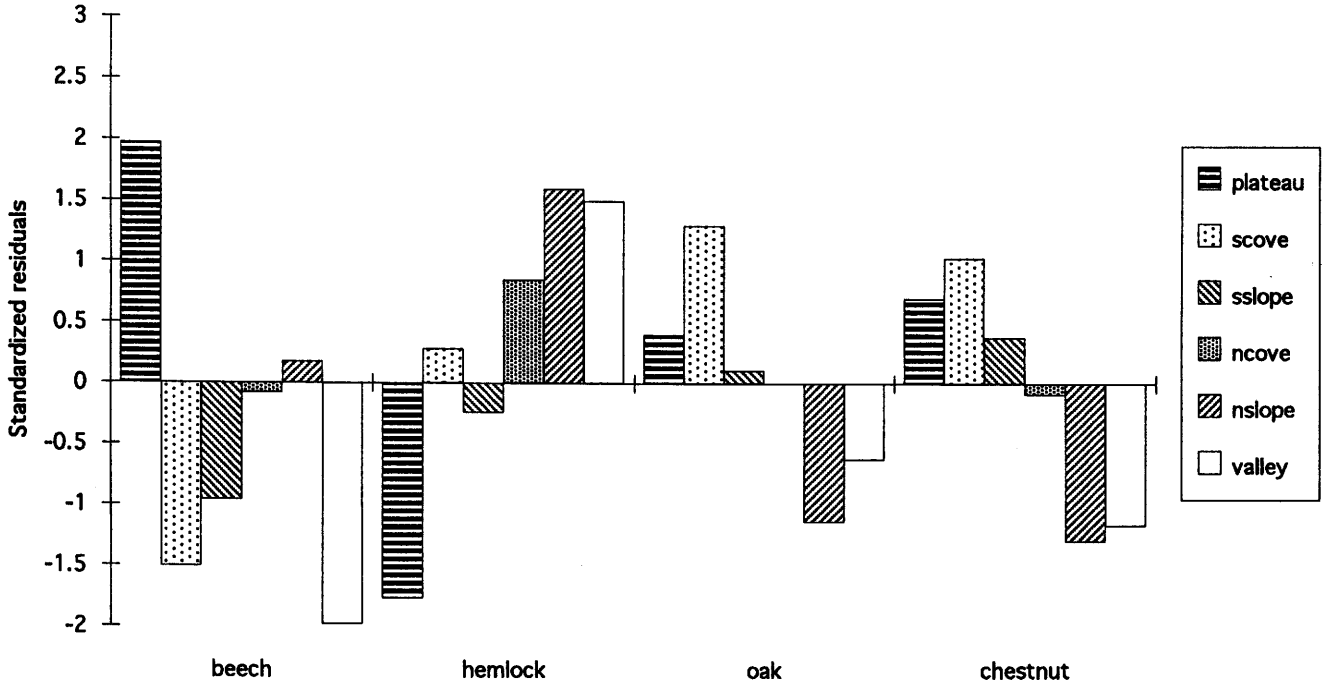

Figure 1.—Significant associations ($p<0.01$) of representative tree species on various landforms of the Allegheny Plateau. Positive and negative values indicate a preference or avoidance, respectively, for the landform.

independence between topographic position and the presence.abscence of a species (Strahler 1978). This test is performed by calculating the likelihood-ratio chi-squared statistic, G^2 and comparing this value to the appropriate quantile of the chi-squared distribution (Agresti 1996). Standardized residuals were calculated following Haberman's method (1973) for contingency tables revealing significance. Residual values quantify a species preference (positive) or avoidance (negative) of a particular topographic position (Whitney 1990).

Analysis of species-site relationships with standardized residuals provided some compelling information concerning species distributions on the Allegheny Plateau. When witness trees across the Allegheny Plateau were used, species distributions conformed nicely to current distributional conventions (Figure 1). For instance, American beech (*Fagus grandifolia* Ehrh.) dominated the plateau uplands while oaks and chestnut (*Castanea dentata*) dominated xeric, south facing slopes. Hemlock (*Tsuga canadensis*) in contrast, was cited most often on mesic slopes and valley/riparian sites.

Following this, witness tree distributions were separated into two zones, west and east of Minister Creek. This boundary was utilized because Minister Creek appears to be a major watershed roughly marking the edge of Native occupation east of the Allegheny River. Thus, witness trees were again tallied by site in these two regions, west and east of Minister Creek. Standardized residuals of species-site relationships reveals significant changes in species distributions (Figures 2 & 3). Ninety-three percent of all oaks and eighty-three percent of all chestnuts tallied occurred west of Minister Creek dominating the plateau uplands and south coves. In contrast, beech is limited to mesic slopes and is virtually absent from the upland plateau. Hemlock is relegated to mesic, protected cove sites. We believe this distinct shift in species on the uplands is a result of Native burning on these sites. Frequent burning would have selected for fire adapted species such as oak and chestnut with their thick fire resistant, corky bark. Further, archaeological sites occur more frequently in the oak-chestnut dominated uplands west of Minister Creek (Figure 4). Species distributions east of Minister Creek are very similar to those cited above for the Allegheny Plateau (Figure 3). Beech again dominates the upland plateaus while oak and chestnut numbers are limited to 6 (7%) and 7 (17%), respectively. We hypothesize that the level of disturbance, particularly fire, was reduced east of Minster Creek and thus late successional beech outcompeted oak and chestnut on the plateau uplands. Further, while some archaeological sites occur east of Minister Creek, they are not as widespread or frequent.

Historical Data

Historical documents such as explorer and missionary accounts, surveyor notes, military journals, and deeds are being searched for information concerning forest conditions and disturbances which may include for instance, Native fires, timber cutting, or agricultural practices. Thus far, early French explorers noted tall-grass prairies along the Irvine Flats of Brokenstraw Creek in Warren Township suggesting a portion of the prairie peninsula may have reached this area (Schenk 1887; Transeau 1935). In 1749, the French Government

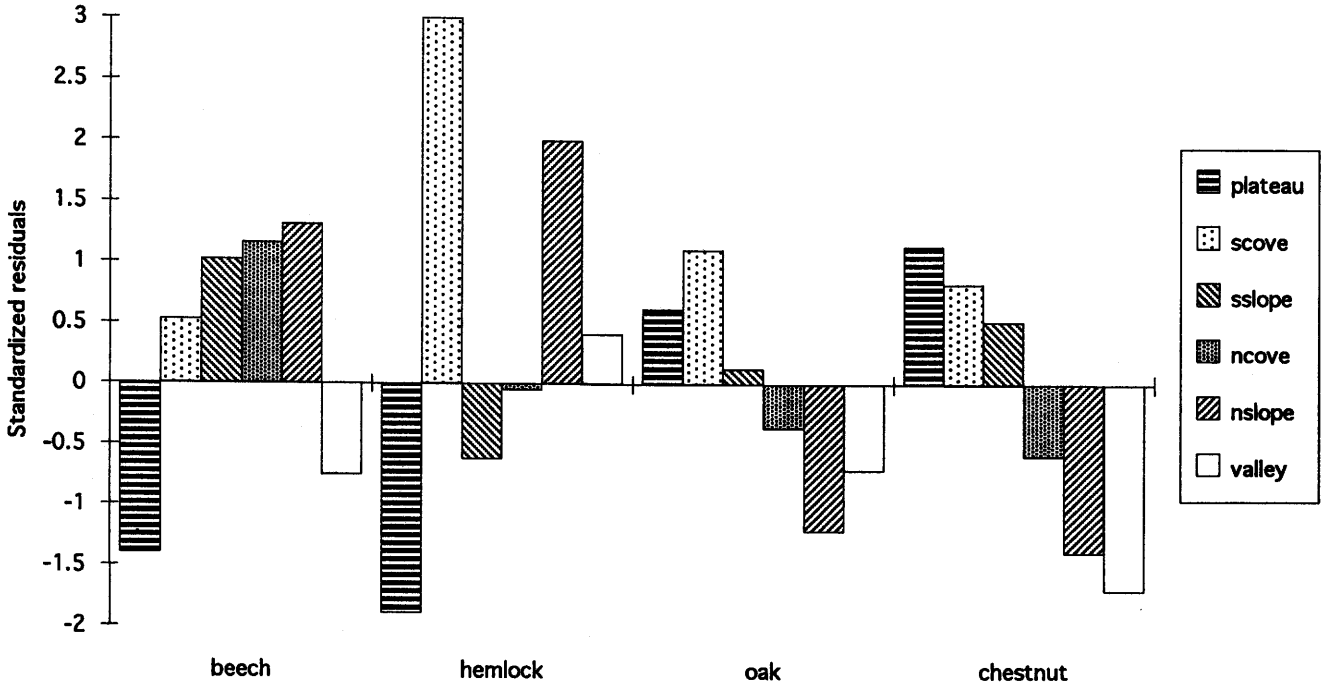

Figure 2.—Significant associations ($p<0.01$) of representative tree species on various landforms west of Minister Creek. Positive and negative values indicate a preference or avoidance, respectively, for the landform.

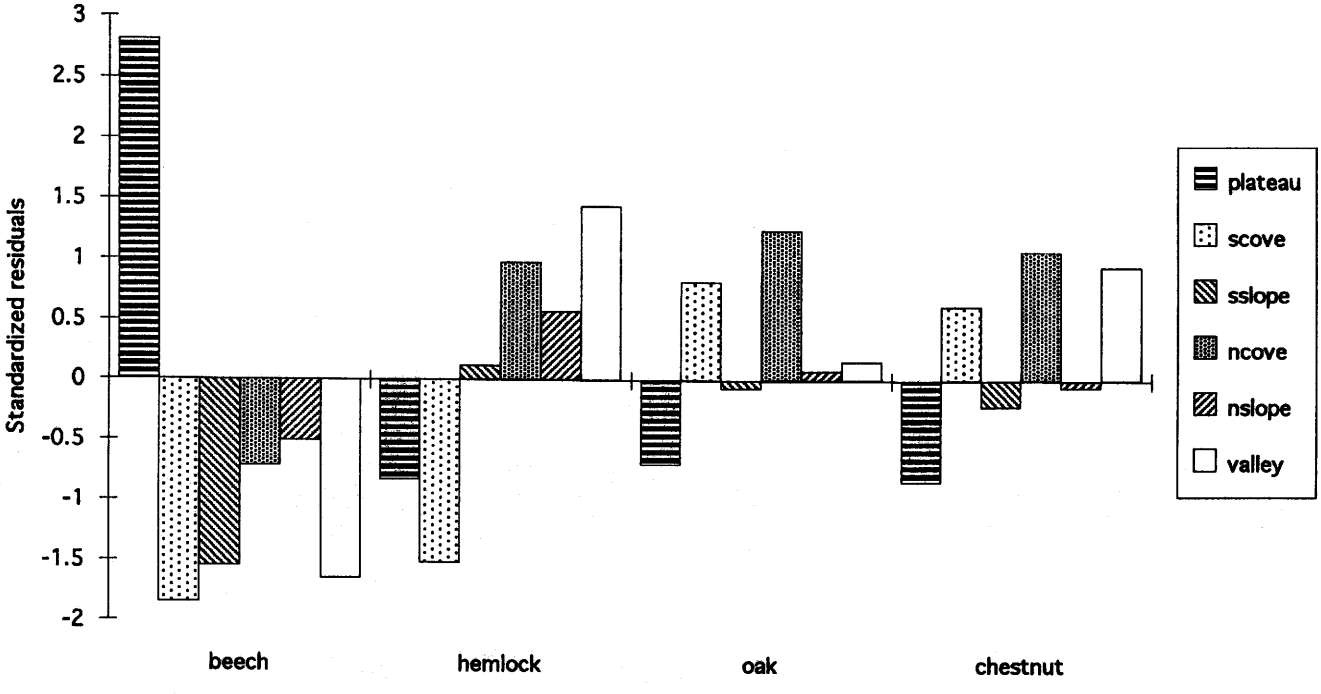

Figure 3.—Significant associations ($p<0.01$) of representative tree species on various landforms east of Minister Creek. Positive and negative values indicate a preference or avoidance, respectively, for the landform.

dispatched Captain Bienville de Celeron to officially claim the lands of the upper Ohio (Allegheny) River. While environmental information is sparse in these accounts, locations of Native villages are well described. Early travelers in western New York reported "oak openings" in areas previously inhabited by the Seneca (Ketchum 1864; Sagard 1865).

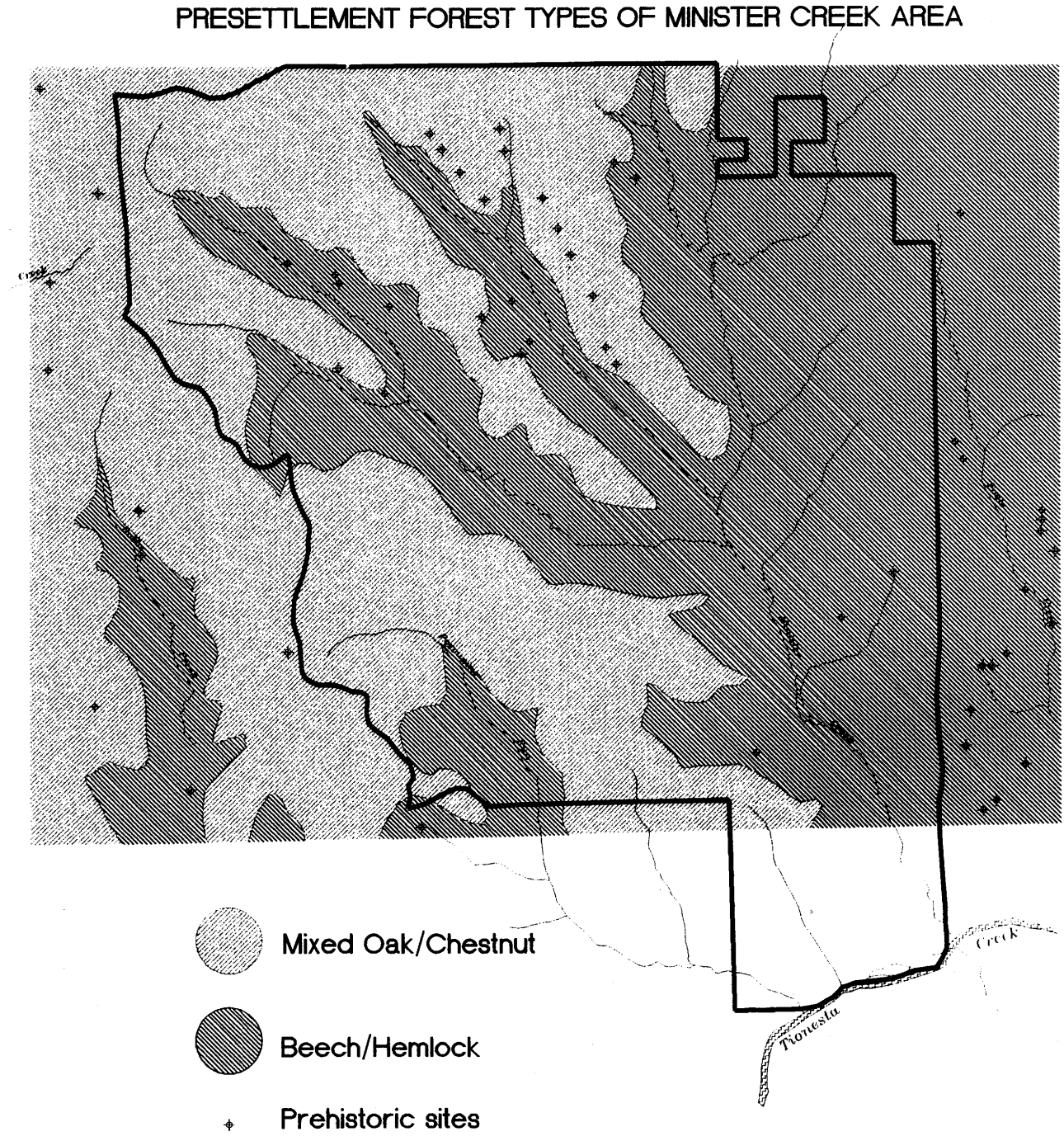

Figure 4.—Presettlement forest types of Minister Creek area with archaeological site distributions. Sites on east side of Minister Creek are camps exhibiting low intensity usage while sites on the west side are characterized by larger rockshelter complexes having extended histories.

Pollen Analysis

The basic assumption of pollen analysis is that the types of pollen depositied at a site represent the range of species growing in the area (Davis 1963; Fagrei and Iversen 1975). The large quantity of pollen mixing in the atmosphere before deposition is assumed to yield a pollen assemblage characteristic of the type of forest or other vegetation that produced the pollen (Kellogg and Custer 1994). Thus, changes in pollen frequencies through time represent changes in vegetation through time (Kellogg and Custer 1994). An exploratory bucket auger sample has been taken and is being analyzed for pollen preservation from the Jones Run bog. A sample from 1.4 m has been submitted for radiocarbon dating. The site appears to have the potential to yield a vegetation record spanning the last few thousand

years. The basal unit is sand-gravel channel deposits, overlain by silt-clay overbank sediments, and capped by sphagnum peat—totaling about 1.5 meters of sediment.

FUTURE WORK

This project is essentially in the implementation stage and final results will not be available until the pollen analysis and archaeological excavations are complete. The authors have developed this study to assess the existence and extent of Native American impacts on natural resources of the Allegheny Plateau. We believe this integrative approach could be utilized in other regions to better understand the long term vegetational changes on the landscape and assess cultural adaptations or disturbances responsible for the anthropogenic landscape encountered by EuroAmericans during westward expansion.

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Communicating the role of silviculture and Forest Service silviculture research in the Interior West.

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Abstract.—Silviculturists create desired forest conditions across the landscape and over time. Our job is to synthesize knowledge from many disciplines to develop prescriptions that produce desired forest conditions. In turn, forest conditions result in products and values for society. Silviculture and silviculture research help provide the scientific basis for land management decisions. Crucial roles for research silviculturists are mensurative studies that quantify resources, manipulative studies that test hypotheses, synthesis, and publication; without these, new knowledge will not be generated and the science of silviculture will progress slowly. Silviculturists are central to implementing Ecosystem Management, and they must communicate the importance of their profession to clients, other natural resource disciplines, policymakers, and the public. A checklist is provided highlighting important points about silviculture and silviculture research.

INTRODUCTION

The following is from an actual job announcement with a USDA Forest Service ranger district in the western United States.

Series/grade: GS-0460-11
Title: Forester (biomass administrator)
Duties: The incumbent serves as a silviculturist with primary responsibility for the development, planning, and application of silvicultural methods and practices.

The duties for this job are clearly that of a silviculturist, but the parenthetical title of biomass administrator suggests a reluctance to use the words silviculture and silviculturist. This job announcement is not an isolated case; rather, it reflects a trend to avoid the "S" word because of perceptions that silviculturists and the practice of silviculture are biased toward the single-minded production of wood products. Too many people think silviculture means tree culture.

At the same time, the profession is experiencing a decline in the number of silviculturists and research silviculturists in the Forest Service. Exact numbers are not available because silviculturists are included with foresters and research silviculturists are counted as research foresters. Nationwide over the past 10 years, the number of research foresters in the Forest Service has declined 61 percent from 350 to 138 positions (Stout 1996). In the Interior West[2], the number of research silviculturists declined 59 percent from 17 in 1980 to 7 in 1997 (Fig. 1). As Figure 1 shows, there has been a steady decline in research silviculturists.

Reduced numbers of silviculturists and research silviculturists brings several questions to mind. Is the vitality of the profession of silviculture in jeopardy? Have silviculture and silviculture research matured to the point that the number of people in the profession can be reduced? What is being lost when silviculture and silviculture research are de-emphasized?

The purpose of this paper is to discuss the role of Forest Service research silviculturists and their interactions with the profession of silviculture, land managers, the scientific community, and the public. The authors' perspective is shaped by working in the Interior West, but the situation may be similar in the rest of the United States. The points discussed in this paper can be used to communicate the role of silviculture and silviculture research to the many and varied publics that we all serve.

EVOLUTION OF SILVICULTURE AND SILVICULTURE RESEARCH

In the Interior West, the profession of silviculture has evolved for nearly 100 years from emphasis on individual trees to emphasis on the components and processes of forests. Silviculture research has prompted changes in silviculture and visa versa. Synergism between silviculture research and the practice of silviculture has advanced the art and science of the profession.

Early silvicultural practices in this country focused on individual trees because of their economic and social importance. Fernow (1916) defined silviculture as the production of wood crops. The economic production of wood for society was the goal of silviculture. Silviculture research investigated the silvics of commercial species, natural and artificial regeneration, tree growth, and relationships between the environment and tree growth. Research logically started with the emphasis on individual trees, but gradually there was increasing research on insects, diseases, fire, non-tree vegetation, soils, and other components of forests.

The advances in knowledge about silvical characteristics of species and growth of trees allowed emphasis to shift to stands of trees. Toumey (1928) and Baker (1934) expanded the definition of silviculture to include methods for establishment and development of forest stands for sustained production of wood crops. Now the emphasis was on stands of trees, but the goal was still wood production to benefit society. Silviculture research also expanded by conducting investigations at the stand level. Yield tables were developed for normal stands, as were stocking tables, thinning guides, and planting guidelines.

Next, silviculture was defined as the theory and practice of producing and tending a forest that best fulfills the objectives

[1]see appendix for author's affiliation
[2]Eastern Washington, eastern Oregon, Idaho, Montana, Wyoming, Utah, Colorado, Nevada, New Mexico, and Arizona.

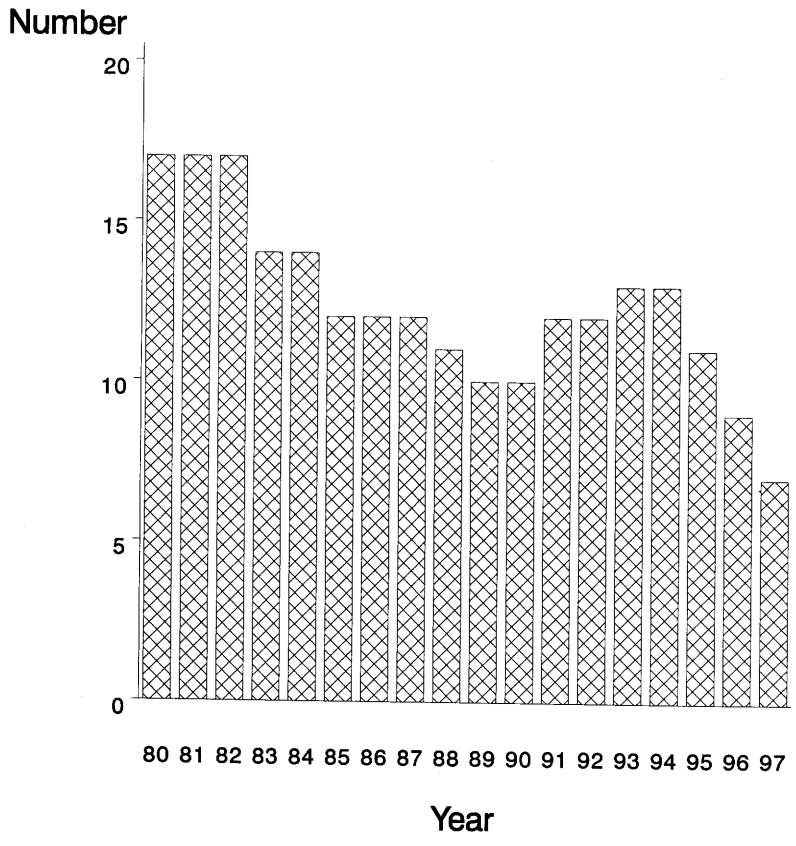

Figure 1.—Number of research silviculturists in the Interior West from 1980 to 1997.

of the owner (Smith 1962). It was no longer assumed that the landowner's objective was the production of wood. This important shift in emphasis recognized that landowners have a wide variety of objectives. Silviculturists developed prescriptions to meet many objectives, which could be as diverse as creating habitat for wildlife, providing clean water, or using genetically improved trees for wood production. The role of silviculture research expanded to use ecological community classifications (for example, habitat types and successional plant communities) that become available in the Interior West (Daubenmire and Daubenmire 1968; Pfister and others 1977; Wellner 1989). Forest growth models were developed, and they were being linked to models that predicted other forest attributes such as shrub cover, impact of insects and diseases, and wildlife (Edminster and others 1990; Moeur 1985; Stage 1973; Teck and others 1996). Silviculture researchers started integrating more ecosystem processes into their studies.

Today, silviculture is defined as "the art and science of controlling the establishment, growth, composition, health, and quality of forests and woodlands to meet the diverse needs and values of landowners and society on a sustainable basis" (SAF 1994). Silviculture is the management of vegetation and creation of forest conditions to meet landowner needs and objectives. Silviculture researchers now explore forest ecosystem processes, structures, and functions.

Where is silviculture in terms of its evolution? Interestingly, silviculture has progressed to meeting the intent of its original definition. The root word 'silva' is Latin for an area of woodland or forest (Glare 1968). The literal translation of silviculture is forest culture. Silviculturists prescribe management for all components of the forest to achieve a wide variety of objectives. The current evolution in silviculture to fully implement forest culture in the Interior West is possible because of the collective experience, tools, and scientific knowledge developed over the past 100 years.

CREATING DESIRED CONDITIONS

If silviculture is the art and science of controlling the establishment, growth, composition, health, and quality of forests and woodlands, how does the silviculturist influence the vegetation to meet needs and values? The answer is that vegetation is managed directly and indirectly to favor the desired outcomes. The kind, amount, intensity, and duration of vegetation manipulation depends on the objective.

Silviculturists create and maintain forest structures and processes that result in the desired forest conditions. Forest conditions result in products. Traditionally, products have been wood, water, wildlife, range, and recreation. Products can be easily quantifiable, like the traditional products, or products can be values such as biodiversity, scenery, and spiritual values. Today's silviculturists are dealing with a wide array of products that the public demands.

Silviculturists create desired conditions across the landscape and over time. They develop knowledge and tools for managing forest vegetation. The job of a silviculturist is to integrate knowledge from many disciplines (ecology, pathology, entomology, mensuration, wildlife, watershed, recreation, genetics, soil science, sociology, economics, and so on) to develop prescriptions that produce desired conditions. Not only are silviculturists skilled at creating desired conditions, they are also trained to understand how historic conditions have shaped current forests and how forests will change over time -- 10, 20, 50, and 100+ years into the future. This knowledge can help create desired conditions for today and for decades to come.

Silviculturists and silviculture researchers consider consequences of their actions in the short-term and long-term. Appropriate silviculture that creates desired short-term conditions may have undesirable long-term consequences. An example would be maintaining continuous tree canopy coverage in a scenic area. Short-term goals can be reached by using uneven-age management. Long-term results will be a shift in species composition from shade-intolerant species to shade-tolerant species. The species, amount, and quality of shrubs, forbs, and grasses will change. Associated with the shift to shade-tolerant species will be changes in animals, insects, fungi, and so on. These changes may be good or bad depending on the objective. Silviculturists communicate information about short-term and long-term consequences, describe alternatives, and develop prescriptions that best meet short- and long-term objectives.

VOLUNTARY AND INVOLUNTARY SILVICULTURE

An important point about little or no silvicultural management is that forests are involuntarily changed by human activity. A lack of planning for the future care, development, and replacement of forests becomes a kind of rudderless drifting (Smith 1962). Humans have changed natural cycles in forests, especially wildfires in the Interior West. Cultivation of land adjacent to forests and extinguishing wildfires have changed the frequency and intensity of fires. Human activity has also affected atmospheric CO_2, high altitude ozone, air temperatures, air quality, wildlife migration routes, gene flow, and the introduction of exotic species of insects, diseases, and plants. We cannot dismiss the existence of involuntary silviculture. It exists and it does have unintentional effects on forests.

Natural resource professionals must consider all consequences of alternative ways that forests can be managed. An example of clear thinking is the discussion about the supply and demand for wood, wood alternatives, and how local and national demand for wood is linked to global supplies (Dekker-Robertson, these proceedings). America is a net importer of wood and Americans use wood at a rate nearly 3.5 times the global average. Alternatives to wood (steel, aluminum, brick, concrete, and plastic) are expensive, consume large amounts of energy during the manufacturing process, and result in CO_2 release into the atmosphere. When demands for wood are not met locally or nationally, forests in other parts of the world are harvested. Ecologically sensitive tropical rainforests or forests in Siberia are much less productive than forests in the United States. In addition, environmental laws in many foreign countries are weak.

Even if the American people decided not to harvest wood from public lands, there are major health concerns for forests in the Interior West. Ecosystems are constantly changing; they do not and cannot remain static. More wood grows per acre per year in Interior West forests than can be decomposed by natural processes (Oliver and others 1994; Olsen 1963). The right combinations of moisture and temperature do not exist long enough each year for wood to decompose as fast as it grows. Fires, insects, and diseases are the disturbance agents that historically recycled excess biomass in the Interior West.

Large amounts of fuel are present in Interior West forests because of fire suppression efforts that began in the early part of this century. Forests that historically burned with low intensity ground fires are now experiencing stand replacing fires. Unacceptable loss of resources and lives are an added expense of fighting wildfires and rehabilitating burned forests. The choices are to manage forests before wildfires or after wildfires; doing nothing is an example of involuntary silviculture.

SILVICULTURISTS ARE INTERDISCIPLINARY GENERALISTS

Many of the disciplines in forestry are specialties that evolved from silviculture, so it is natural that there is a good deal of overlap between silviculture and other forestry specialties. For example, a forest entomologist must understand the habitat that supports insects and how that habitat influences life cycles, predators, hosts, and so on. But, silviculture is the one discipline where knowledge from many other disciplines is deliberately brought together to develop management prescriptions that meet owner's management objectives. Necessarily, a silviculturist is a generalist who must interact with others to develop the best possible prescriptions.

The integration of knowledge from many disciplines also means silviculturists work in an interdisciplinary manner with many people. Decisions concerning any one discipline in forestry cannot be made independently from other disciplines. Since most decisions will directly or indirectly involve vegetation management, the silviculturist is a key person on interdisciplinary teams. One job of the silviculturist is to help people understand the consequences of proposed alternatives. By collaborating with other disciplines, results of various alternatives can be described and displayed over time. Then, landowners can make more informed decisions.

THE ROLE OF FOREST SERVICE RESEARCH SILVICULTURISTS

The future is always uncertain; however, several things seem clear. The world's population is continuing to grow and people will increase their standard of living whenever possible. Current alternatives to wood are not as economical, are not renewable, and their production uses more energy and creates more pollution. Therefore, the demand for wood products will remain high. At the same time, greater demands are being placed on forests for other products such as clean water, wildlife, recreation, biodiversity, and forest health. The public expects science-based management of forests. Increasingly complex silvicultural prescriptions will be required to achieve multiple goals from forests.

Forest Service research silviculturists help envision and create the future forest under different management options. They need foresight to keep ahead of issues. Following are

general areas of research in Interior West forests where silviculture research expertise is needed. Most of this research will require an interdisciplinary approach with researchers in mensuration, entomology, pathology, wildlife biology, social sciences, and so on. It will also require collaboration with user groups, universities, and other research organizations.

1. Forest development, naturally and with management.
2. Silvicultural systems for forest health and sustainability, and for resistance and resiliency to pests.
3. Management of biomass accumulation.
4. Silviculture for threatened and endangered plants and animals.
5. Silvics of previously unmanaged species.
6. Linking terrestrial and aquatic ecosystems.
7. Techniques and tools for communicating with each other and the public.

Forest Service silviculture researchers most often seek answers to applied, rather than basic, research questions. This pragmatic approach to research lends itself to close collaboration with user groups to identify research topics, conduct the research, and transfer research results into application.

The ability to conduct long-term research is a strength of Forest Service Research. There are two types of long-term research. First are studies where variables are remeasured over long time periods. Examples are measuring permanent sample plots, monitoring the flow of watersheds, and testing genetically improved trees. The second type of long-term research deals with a series of interrelated studies that must be conducted to gain knowledge about large, complex problems. For example, whitebark pine (*Pinus albicaulis*) is a keystone species in high elevation ecosystems. Seeds from whitebark pine are very important in the diet of grizzly bears (*Ursus arctos horribilis*), Clark's nutcracker (*Nucifraga columbiana*), and red squirrels (*Tamiasciurus hudsonicus*), but whitebark pine is being decimated by white pine blister rust (*Cronartium ribicola*). Research is needed to understand many things about whitebark pine, including more about silvics, reproduction, growth, nursery practices, planting methods, competition, genetic variability, and mechanisms of resistance to blister rust.

A relatively stable research program makes it possible to conduct both types of long-term studies. With stable funding, it is possible to plan and carry out long-term studies. Scientific and technical staffs provide continuity of research and safekeeping of records. But, long-term studies should be designed to give interim results that can be applied as soon as possible. Interim results are needed to help managers who must make decisions using the best available knowledge. Scientists working on both long- and short-term studies is a good balance.

Forest Service research silviculturists also conduct short-term studies very well. A trained and experienced workforce is well suited to conducting studies that can be complex and comprehensive. Forest Service research silviculturists also have opportunities to conduct research in a variety of ecosystems, which provides a breadth of knowledge and expertise.

The interaction among today's Forest Service silviculture researchers, colleagues, and clients is surprisingly complex. Studies are designed to answer complex questions about how biological systems function and how processes and structures interact. Collaborative efforts are essential to accomplishing the research. It is important that administrative boundaries do not impede cooperation among researchers because scientists need the freedom to pursue avenues of investigation that will provide answers to important management questions. The best collaboration begins at the grass roots level; generally a group of scientists and clients define a research need, decide upon a course of action, gather the necessary resources, and conduct the research. Grass roots collaboration needs to be protected and nurtured.

Forest Service research silviculturists have many clients. In the Interior West, users of Forest Service silviculture research include the Forest Service National Forest System, Forest Service State and Private Forestry, private industry, universities, state forestry departments, other Federal agencies, private landowners, Indian tribes, other scientists, environmental groups, and extension and consulting foresters. Research topics are chosen after consultation with clients, but research is not directed by user groups.

Independence of Forest Service silvicultural scientists is necessary. Autonomy is important because scientists are judged on their objectivity and independence to pursue the truth. While maintaining independence, silviculture researchers must work collaboratively with user groups to be familiar with their needs and to conduct high quality research. Unless scientific investigation is sustained, there will be no new technology to transfer (USFS 1995).

There are three main tasks in a Forest Service research silviculturist's job.

1. Scientific investigation.
2. Technology transfer.
3. Information and expertise.

Scientific investigation for a research silviculturist includes mensurative studies that quantify forest attributes (to answer "What is?"), manipulative studies that test hypotheses (to answer "Why?"), and synthesis of knowledge into recommendations (to communicate "How to"). Mensurative studies (Hurlbert 1984) provide information about forestry resources; for example, height-age relationships for regeneration or annual production of wildlife browse. Manipulative studies (Hurlbert 1984) that test hypotheses are crucial to explaining observed phenomenon and helping determine cause-and-effect relationships. Synthesis is a larger part of a research silviculturist's job than for other forestry disciplines. Research silviculturists integrate knowledge from many disciplines to develop and test systems, tools, and methods that can be used to meet a

variety of goals. Integration requires a fundamental knowledge of many other disciplines.

Publication of research results is the most important step in technology transfer, but it does not stop there. Scientists make presentations at meetings, participate in field trips, and provide training. Demonstration areas also show results of research. Advances in technology such as videos and the Internet provide new ways of getting information to users.

Information and expertise is exchange of ideas and knowledge. Other duties of research silviculturists include consulting, special assignments, or involvement in inventory and monitoring. Consulting may be adapting knowledge gained in one ecosystem to another ecosystem, interpreting the accumulation of literature on a particular subject, or reviewing recommendations that are based on the scientist's research. Today's special assignments involve participating on assessment teams, writing management guidelines for threatened and endangered species, and helping implement ecosystem management.

The fundamentally important parts of a Forest Service research silviculturist's job are mensurative studies, manipulative studies, synthesis, and publication. If these tasks are not done, the science of silviculture will advance slowly. Mensurative studies quantifying biological relationships. Manipulative studies test hypotheses and help determine cause-and-effect relationships. Synthesis is the process of integrating new knowledge with existing knowledge and practices to develop improved management strategies. And, of course, research findings must be published so that the new knowledge is available to current and future generations.

CONCLUSIONS

The number of Forest Service silviculturists and silviculture researchers has steadily declined despite the need for both. Demand for products from forests will remain high because of expanding populations, rises in the standard of living, and increasing demands for a variety of products. The products from forests can be traditional products (wood, water, wildlife, range, and recreation), newer products (such as yew bark, mushrooms, and beargrass), or values (such as spiritual values, biodiversity, and forest health).

The profession of silviculture has a very important role in helping achieve the goals of forest management. The importance of that role must be communicated both internally and externally in a variety of ways and to a variety of publics. No one approach will reach the various publics because different groups have diverse knowledge about natural resources, forestry, and silviculture. However, the messages that need to be communicated are the same. Following is a listing of points about silviculture and silviculture research that are important to communicate to each other and the various publics we serve.

- Silviculture means forest culture. Silviculturists plan and implement treatments with all components of forest ecosystems in mind. Research silviculturists design research studies that consider all components of the forest.

- The choices are to silviculturally manage forests now or rehabilitate them later. This is especially true in the Interior West where wildfires, insects, and diseases have historically recycled accumulated biomass.

- Silviculturists realize that all forests are being managed because they are being managed either voluntarily or involuntarily. Involuntary silviculture occurs when there is a lack of planning for the care, development, and replacement of forests.

- Silviculturists are interdisciplinary generalists. Silviculture is the profession where knowledge from many disciplines is deliberately synthesized and applied.

- Silviculturists help achieve land management objectives. Objectives can be tangible products or less-tangible values.

- Desired conditions are created by manipulating vegetation to favor some species over other species. Conditions are created over time and across the landscape.

- The art and science of silviculture have co-evolved from growing trees, to stand management, to stand ecology, to landscape ecology.

- The profession of silviculture has accumulated enough tools, experience, and scientific knowledge to begin forest culture.

- And it is silviculturists who have the broad ecosystem-based training to do ecosystem management.

- Silviculture and silviculture research have short- and long-term perspectives. The consequences of short-term results must be considered in the context of long-term forest development.

- The fundamental roles of Forest Service silviculture research are mensurative studies, manipulative studies, synthesis, and publication. These four roles move the art and science of silviculture forward.

- Forest Service research silviculturists have many clients. Research topics are chosen in collaboration with clients, but research is not dictated by any client or user group.

Those of us in the profession of silviculture must be proactive in communicating the importance of silviculture and silviculture research. Good silvicultural practices will make people feel good about forestry and bring more credibility to natural resource management. Silviculturists *manage* to bring out the best from our forests.

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The Value of Long-term Silvicultural Research Studies

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Abstract.—Reductions in research operating budgets and recent trends in research management philosophy have in many instances forced Forest Service scientists to realign their research programs to compete for short-term grants and other sources of funding. This approach may prove detrimental in silviculture, a discipline where long-term research is critical for: (1) research in the regeneration and establishment of forests, (2) testing management alternatives in established stands, (3) retaining research installations for future remeasurement; using them as laboratories for other disciplines, and adapting them to meet current and future needs. We present specific examples from our own experience where long-term studies have been utilized in these capacities.

INTRODUCTION

Neither of us confess to being dedicated followers of Forest Service policy, but our keen scientific minds and combined 50+ years of experience with the agency have enabled us to perceive what we consider to be disturbing trends in Forest Service Silvicultural Research. First of all, we've noticed that we simply don't have as much money to spend on our research as we once had. With smaller budgets, we can't afford to do large-scale experiments in a time of increased emphasis on landscapes and ecosystems. We have also noticed that a lot of our colleagues have disappeared too. We now compete with our academic friends in seeking soft money to fund research.

There are several changes in management philosophy within the Forest Service that have affected our discipline. There has been a movement away from commodity-oriented management with an accompanying emphasis on other resource values during the past few years. We are not suggesting that this has been wrong, but do wonder if the pendulum has swung so far that some basic principles of forestry have gotten trampled in the process.

Another contributing factor is the need for quick answers in today's crisis-to-crisis management environment. Managers simply don't have time to wait for the results of long-term studies to become available. As a result there is a perception that the need for silvicultural research has been reduced. The arguments for this position is that silviculture research is no longer pertinent to current management needs (e.g. we aren't growing timber anymore, we already know everything we need to know about growing trees, we need to learn more about ecosystems, etc.).

The scientific culture of rewarding scientists for the number of scientific publications produced is also detrimental to long term studies. Neither the scientist or the supporting agency are eager to initiate research efforts where investments are slow in producing rewards. This is especially true for scientists performing silviculture research where it may take years for trees to respond to treatment.

We feel that subscribing to these attitudes overlooks several critical issues. Trees are the defining component of forested ecosystems and we do still need to learn more about their biology, care and management. This is especially true as we seek new ways of maintaining and managing these ecosystems for purposes other than commodity production. For example, we know a lot about managing forests to produce wood fiber, but need to learn more about managing trees to maintain old growth, provide wildlife habitat, and reduce the risk of catastrophic disturbance in urban-interface and other high-value environments. We have learned much about the biology of tree species that have been utilized for wood products, but know little about many "non-commercial" species in our forests. We have well developed silviculture techniques for managing even-aged, single-species, forests, but need to refine un-even aged management techniques in mixed species forests and at landscape scales. The word "forest" is still in the name of the agency and as long as it is, we need to concern ourselves about trees as well as other natural resources.

Because trees are long-lived and grow slowly in some environments, silviculture is a discipline where long-term research is critical. Since the Forest Service has been managing trees for a long time and has established an infrastructure of facilities where long-term studies can be maintained, we feel Forest Service researchers are uniquely capable of conducting such studies. Our scientists have access to the largest network of experimental forests in the world, many of which have on-going studies that have been in place for decades. This gives us a tremendous advantage over our academic and industry colleagues, whose access to long-term study sites is limited, or driven by production forestry goals. We should not forsake these resources because of changes in public land management philosophy.

Our theme here is to remind our colleagues that silviculture is still a viable discipline, and that management of trees will still be done in the future. Although it may not be commodity-based as in the past, silviculturists are uniquely qualified and positioned to take the lead in planning and applying that management. Furthermore, we advocate that silviculture researchers should utilize existing and new long-term studies and installations to develop vegetation management techniques that can provide the attributes desired for our public lands.

DISCUSSION

Long term studies are critical to several areas of silviculture research and will be a key element to the development of

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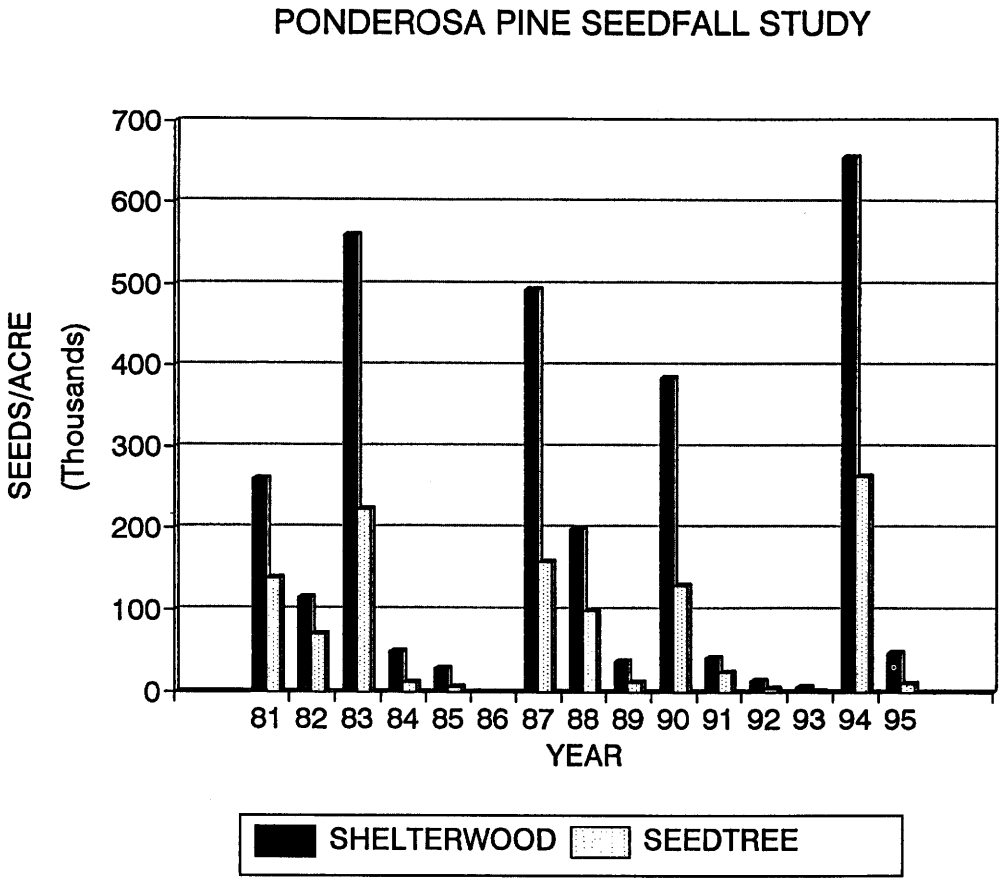

Figure 1.—Annual seedfall of Front Range ponderosa pine under shelterwood and seedtree overstories, 1981-1995.

new vegetation management techniques. For example, research in the regeneration and establishment of previously unmanaged species cannot be adequately done without long-term studies of the factors that influence growth and survival over time. No other method can furnish the necessary data. Similarly, long term studies are useful to test new management alternatives in established stands. Measuring growth responses to thinning and other density and structure control techniques over time is the only reliable way to collect the data needed to develop and refine growth and yield models. This kind of long-term research can be useful not only to forest management, but also to other disciplines such as basic ecological research. Long-term studies can provide data on tree biology that would be useful in developing process-based models in addition to growth and yield models. Long-term studies could also be useful in the science of developing monitoring protocols.

Our agency has adopted an adaptive management philosophy; a similar adaptive approach is needed in the management of long-term research installations. Retaining these research installations as field laboratories and adapting them to new uses is another way of utilizing these extremely valuable resources in answering new research needs. Installations that were established for one purpose can often be used for new research, with the existing data providing a critical historic reference to set the context of the new research.

To underscore the continued need for long-term research within our agency, we would like to present several examples from our own experience to illustrate how long term studies can meet these needs.

Manitou Experimental Forest Ponderosa Pine Regeneration Study

This study was established in 1981 to compare seed tree and shelterwood regeneration methods in Front Range ponderosa pine in Colorado. As part of the original study, we installed a grid of 900 seed traps and 450 6 x 6 ft. plots to monitor seedfall and seedling establishment. Fifteen years of monitoring have given us a very good picture of the periodicity of seedfall in Front Range ponderosa pine as well as a much better understanding of the growth and survival rates of natural pine seedlings. It is becoming increasingly apparent that good seed crops occur every 3-4 years in this environment, but usually not sequentially (Fig. 1) and that seedling survival follows a similar trajectory, regardless of the year of germination (Fig. 2). Our observations of differential seedfall and establishment from plot to plot have prompted us to initiate new research on the site to identify micro-climatic, soil, or topographic features that might be responsible. We have also mapped the position of overstory trees in an effort to identify and characterize those which produce consistently good seed crops. None of this research would have been possible using short-term studies.

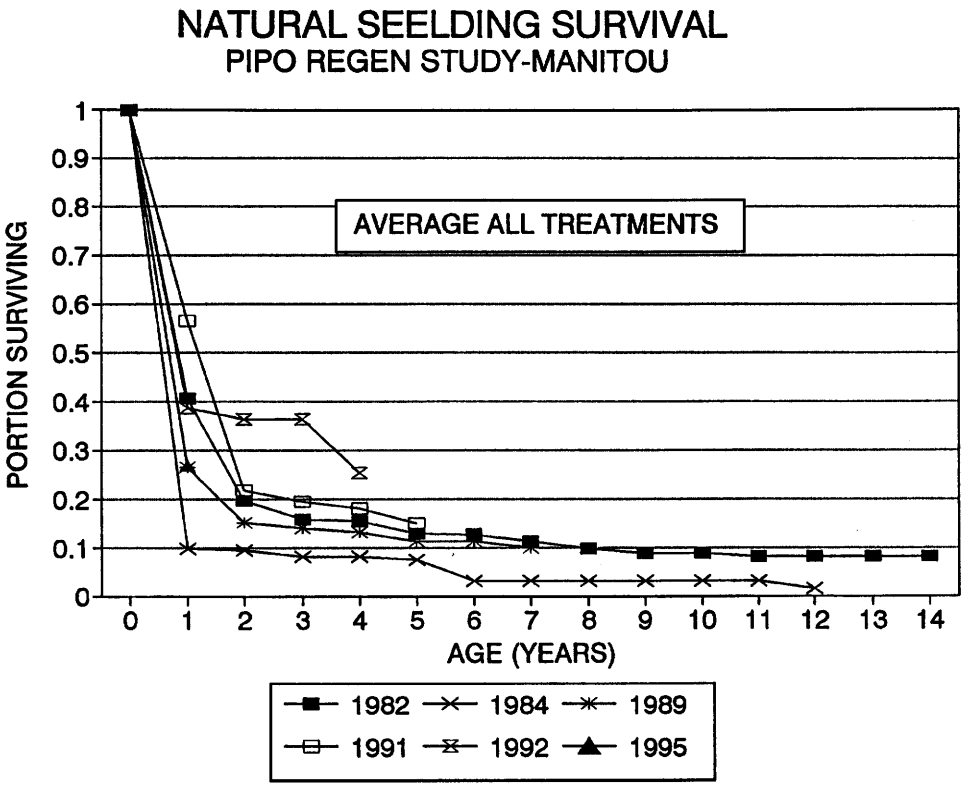

Figure 2.—Portion of ponderosa pine seedlings surviving to a given age, by year of germination.

Fraser Experimental Forest Engelmann Spruce Seed Production Study

This long-term regeneration study was installed in 1969 specifically to monitor seed production in natural high-altitude spruce stands (Alexander and Noble 1976). Although our continuous record of seed production is unique, perhaps the most valuable aspect of this study is the repeated inventory of the thirteen undisturbed old-growth stands surrounding our seed traps. This data will soon give us a thirty year record of mortality, recruitment, and growth in these stands. This study is an excellent example of adapting an existing long-term study for new, unanticipated uses.

Engelmann Spruce Provenance Plantation

This study was planted in 1970 as part of a national test of Engelmann spruce seed sources collected from throughout the natural range of the species (Shepperd and others 1981). Not only has the 25 years of survival and growth records given us valuable information about genetic variation within the species, it has also served as an excellent demonstration of the long-term value of using proper planting techniques at high altitudes. Following guidelines developed by former Rocky Mountain Station scientist Frank Ronco (Ronco 1972), we have achieved an overall survival of nearly 70%, 25 years after planting, and have clearly established that most mortality occurs in the first few years after planting. Such long-term quantitative planting records are unique in our experience and are invaluable in training new generations of reforestation specialists.

Fraser Experimental Forest Cutting Methods Study

Originally established to test and compare the efficiency of harvesting Engelmann spruce and lodgepole pine under even- and uneven-aged management, this study's most important role has been as a demonstration area where professional and lay visitors can view examples of correctly-applied silviculture, see first-hand the differences between even- and uneven-aged management, and discuss the benefits/trade-offs for other resources. It has been especially beneficial to natural resource professionals who do not have a forestry background. The uneven-aged sites have also benefited silviculturist trainees who can view diameter distribution Q curves applied on-the-ground.

The Fort Valley Experimental Forest Levels of Growing Stock Study

This ponderosa pine research was initiated to study the effects of stand density management on the development of second-growth stands. The Taylor Woods installation at Fort Valley Experimental Forest near Flagstaff, Arizona, is the oldest of four similar installations west-wide. The area at Taylor Woods was commercially harvested in winter 1923-24 and contained an understory of saplings established in 1914 and smaller seedlings established in 1919. This aspect of the study certainly qualifies as research in the regeneration and establishment of forests and illustrates the value of having long-term data from a site.

The second-growth stand that developed from these saplings was initially thinned by Gilbert Schubert in 1962 (Schubert

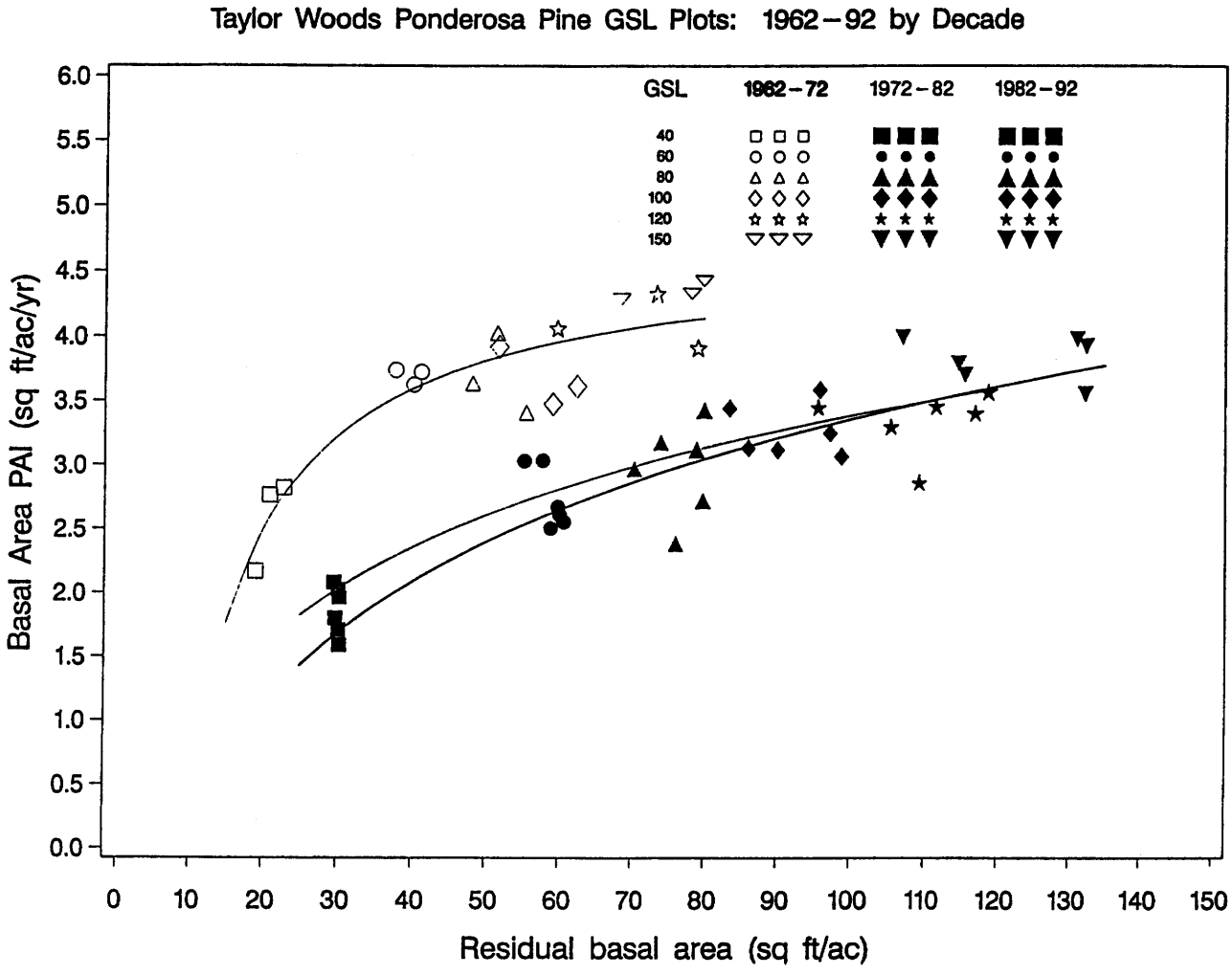

Figure 3.—Basal area growth by growing stock level (GSL) calculated prior to thinnings at 10, 20, and 30 year intervals, Taylor Woods levels of growing stock study.

1971) under a study plan written by Clifford Myers (both former RM scientists). All the large trees remaining after the 1923-24 cut were harvested in the early 1960's, prior to the study initiation.

Basal area annual growth rates varied by stand density as would be expected, but growth also varied for each 10-year remeasurement period after thinning (Ronco et al. 1985). Note how the growth was different during the initial period showing an adjustment to growing space after the first thinning, and fairly consistent during the next two periods (Fig. 3). This is an excellent demonstration of why permanent installations are a most effective tool for researching and demonstrating long-term stand dynamics. A ten year study would have given much different results that the thirty-year study has revealed.

Taylor Woods has not only been a test of management alternatives. It is also an excellent example of how long-term research installations can be retained as field laboratories and adapted to new uses. Taylor Woods has been used to study the effects of density management on wood quality of harvested trees, mushroom production as a food source for Abert's squirrels, understory herbage production, resin production and photosynthetic rates, and canopy cover. While there has been a shift away from even-aged management in the Southwest, the study provides an excellent example of how the rates of tree development can be controlled by managing stand density to obtain variability in tree sizes in even-aged forests. Standing and discussing the real thing is better than a conference room any day. Permanent research installations are critical demonstration areas and an important communication tool for both research and management.

North Kaibab Ranger District Group Selection Study

This recent study installation for uneven-aged management of ponderosa pine on the North Kaibab Ranger District, Arizona is an example of how we envision long-term studies might be continued in the future. It seeks to determine the effects on stand dynamics when an unregulated large-tree component is retained with a group selection cutting method

at various residual density levels, such as would be done for wildlife habitat. In this study, large-tree groups have been retained, where in traditional uneven-aged management many would have been harvested. The study will provide basic information on growth rates of smaller trees, such as those regenerated from a previous group selection treatment in the study site. In addition, the study is also investigating the effects of prescribed burning on the survival and growth of residual trees of all sizes, future regeneration establishment, and snag longevity.

By sharing resources and a study design such collaborative long-term research efforts are more cost effective than single discipline studies. In addition to research funding, Timber Management and the Kaibab N.F. also contributed funding and resources to facilitate plot establishment and treatment. Research collaborations such as the Kaibab study give silvicultural researchers the resources to provide leadership in adaptive management. Providing the site and resources to help establish this study has given Forest personnel a vested interest and feeling of ownership and responsibility for this study. This is extremely important in maintaining long-term studies, especially those established off experimental forests. Such partnerships are critical to the success of our research program and we advocate their use elsewhere.

CONCLUSIONS AND RECOMMENDATIONS

We feel that long-term silviculture research is an investment that pays real dividends over time. It will be beneficial for the Forest Service to continue to do long term research as public land management policy evolves. Our experience with the studies we have discussed here has convinced us that our agency has a unique advantage over other research organizations in that we have access to the facilities, control of the land, and the continuity of personnel to engage in such studies. Long-term studies have always been a key part of the Forest Service's research program. We feel they should be retained, adapted and strengthened in the future to meet our agency's changing information needs.

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Defining the Role of Silvicultural Research in the Northeastern Forest Experiment Station

Chris Nowak, Susan Stout, John Brissette, Laura Kenefic, Gary Miller, Bill Leak, Dan Yaussy, Tom Schuler, and Kurt Gottschalk[1]

Abstract.—Research planning in the Northeastern Forest Experiment Station has followed a grass roots model for more than two years—ROADMAP, a research and development management plan. The goals for research within ROADMAP include understanding, protecting, managing, and utilizing forest ecosystems. There are nine research themes set to help achieve these goals, each with a set of research initiatives that describe contemporary and future science. Development of the "Silviculture and Resource Management Theme" has helped the Station define and communicate the role of silviculture to a variety of audiences. This paper presents the silvicultural statement developed by a core group of Station scientists.

INTRODUCTION

Research planning in the Northeastern Forest Experiment Station has followed a grass roots model for more than two years—ROADMAP, a research and development management plan[2]. This effort is grass roots because Station scientists are guiding and coordinating Station-level dedication to research problems, including resource allocations. Nine themes are being used by scientists to describe and plan Station research: Basic Processes, Disturbance and Ecosystem Dynamics, Forest Products and Use Economics, Inventory and Monitoring, Managing Forest Health, Silviculture and Resource Management, Social and Economic Dimensions, Systems Modeling and Integration, and Wildlife. The research of the Station is organized to provide regional, interdisciplinary, and long-term support for understanding, protecting, managing, and utilizing forest ecosystems in partnership with scientists at universities and in industry.

Each theme was developed by a team of scientists from across the Northeastern Forest Experiment Station. The "Silviculture and Resource Management" team had nine members, many considered core Station silviculturists and all co-authors of this paper.

Science at the Station exists along a continuum from basic science through application to management and policy. Each team's responsibility was to define where that team's position is along the continuum, that is, we had to define our role in the Station and then communicate it to our colleagues and stakeholders. In this paper, we describe the role of silvicultural research within the Station as developed for ROADMAP. Each team was given a list of questions to answer in a single statement. We modified this list as a framework for this paper.

WHAT IS SILVICULTURAL RESEARCH?

Silvicultural research provides options for practical, sustainable management of forests to produce a variety of outputs and outcomes. Options include different methods and guidelines for practical management of forest ecosystems to meet landowner objectives, and to sustain benefits in perpetuity (Nyland 1996). Included in this research is developing the ability and tools (models) to forecast likely outputs and outcomes from a given set of silvicultural treatments. Benefits achieved by silviculture include those directly or indirectly from the trees themselves, other plants, water, wildlife, and minerals found in forested areas, and a host of intangibles that people realize through recreation and other noncommodity uses (Nyland 1996).

Silvicultural research uses manipulative field experiments or computer simulations to test methods and practices for managing vegetation to achieve desired conditions. Density, structure, and species composition are directly altered by cutting, herbiciding, fertilizing, planting, pruning, firing, or otherwise disturbing vegetation. Treatments alter stand conditions to favor the regeneration or growth of desirable plant and animal communities, and positively affect ecosystem functions and processes such as the hydrologic cycle or energy transfer. Silvicultural research includes the study of linkages between ecosystem attributes and associated plant and animal communities.

Silvicultural researchers develop technical guidelines in the context of both ecological capabilities and social constraints. It is the responsibility of the research silviculturist to execute or instigate biological and ecological studies in support of the development of management guidelines and options, and to integrate new and existing basic information into those guidelines. In doing so, guidelines are likely to produce consistently predictable and sustainable outputs and outcomes, and research results will be more readily adapted to areas outside the study locale.

WHY SHOULD THE NE STATION CONDUCT SILVICULTURE RESEARCH?

The Station is located in an area of little federal ownership. The region's industry consists primarily of small- to medium-sized firms. Eighty-five percent of forest lands are held by non-industrial owners with small ownerships. The forest landowners in the Northeast do not have the resources or

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[2]Unpublished document on file, Northeastern Forest Experiment Station, Director's Office, Radnor, PA.

level of commitment to do long-term research necessary to develop silvicultural knowledge. The Station has a commitment to long-term research, and has an unparalleled base of long-term studies. Many studies established in the 1930's are just beginning to produce the intended research outputs for which they were established. Furthermore, landowner values change. New developments emerge from science. Technology is improved. Society's attitudes evolve. And the forest changes. All of these factors combined cause a continuing need for new silvicultural research.

Silvicultural research has been a mainstay of the Station for 75 years. Many laboratories were chartered and companion experimental forests established to conduct this research. The Station is conducting more than 80 long-term studies in association with Region 9's national forests, mostly on the Allegheny (n=31) and Monongahela National Forests (n=33). Most of these studies are maintained on the Kane and Fernow Experimental Forests. These studies, and dozens of other studies conducted with non-federal partners, are the Station's primary strength as a research organization and a testament to the Station's commitment to silvicultural research.

HOW WILL THIS RESEARCH BE USED?

A range of silvicultural options for multiple forest outputs and benefits will continue to be developed, both by refining and extending existing knowledge and developing new methods and guidelines. Customers to be served with these options include land managers (national forests, state agencies, industry, consultants), universities, Cooperative Extension, state Forest Stewardship programs, State and Private Forestry, environmental organizations, and the general public. Forest managers in the Eastern U.S. will make better decisions regarding forest manipulations and forest management because of our research. National Forest and state forest plan revisions, many slated for completion by the year 2000, will better incorporate silvicultural and resource management issues and solutions for a changing forest resource and changing client demands.

Most of the silvicultural guides developed over the past 75 years were developed by the USDA Forest Service. University curriculum in forestry prominently includes many of the silvicultural principles and practices developed by Forest Service researchers. As research results are published, new silvicultural knowledge is integrated into curricula to help produce well-trained professionals. Similarly, silvicultural researchers are keyed to directly interact with customers through a variety of training sessions, field tours, and other technology transfer activities.

Historically, silvicultural and resource management principles and practices have been well adapted by owners and managers of large land areas, but not by the Northeast's dominant body of forest-land owners—the nonindustrial private forest-land owner (NIPF). As the Northeast's forest matures, pressure to harvest the timber resource across the Eastern U.S. is increasing, especially on NIPF lands, so research must be applicable to these lands. We need to develop silvicultural guides that will allow NIPF's to make more informed decisions regarding the management of their forest lands.

WHO IS DOING THIS RESEARCH?

Centers were established over 50 years ago to provide regional coverage of the major forest types: northern conifer and northern hardwood (Durham, NH), northern hardwood and Allegheny hardwood (Warren, PA), Appalachian hardwood, transition oak, and oak-hickory (Parsons, WV) and oak-hickory (Delaware, OH) (Fig. 1). Each of these units is the steward of at least one experimental forest. Eight Station scientists are focused primarily on silviculture and resource management research in these four units, while the research program of an additional 25 scientists includes some research in this theme, for a total of 11 scientist years, or about 11 percent of Station resources, both staffing and dollars.

WHAT ARE THE RESEARCH INITIATIVES?

During the ROADMAP process, the team described the direction for silvicultural research in three major initiatives: regeneration, multiple tangible outputs, and intangible outcomes.

Regeneration Initiative

Developing regeneration practices that work for all ownerships is the foremost research initiative. Understanding regeneration patterns and processes is critical to sustainable resource management and a cornerstone of future silvicultural research. We will focus research on developing desired mixed-species regeneration in northern hardwoods and conifers, Allegheny and Appalachian hardwoods, northern conifers, and a variety of oak forest types, including transition oaks and oak-hickory. Fire as a tool will continue to be studied to regenerate the oaks. Planting guides will need to be refined and developed not just for oak, but for other species too. And for some species, especially oaks on mesic sites, maintaining the planting investment will mean a need for new research information on weeding and cleaning. Regeneration research will occur in even-age systems, uneven-age systems, and new practices will be developed for the emerging two-age system. This new system will be important as it relates to NIPF lands. Partial cuts made on private lands often result in two-aged stands.

Example No. 1.—Understory vegetation responses to thinning have received little study, primarily because the focus has been on the residual overstory trees. Understory responses to thinning may affect subsequent efforts to regenerate. Aesthetics and wildlife habitat may also be affected. We have begun to examine the long-term effects of thinning to different residual densities and structures on understory development (Yanai, in press). Study treatments include a thinning from above, which emulates diameter-limit cutting, a common non-silvicultural practice on private lands.

Example No. 2.—Uneven-age silvicultural studies on the Bartlett Experimental Forest have featured the use of group

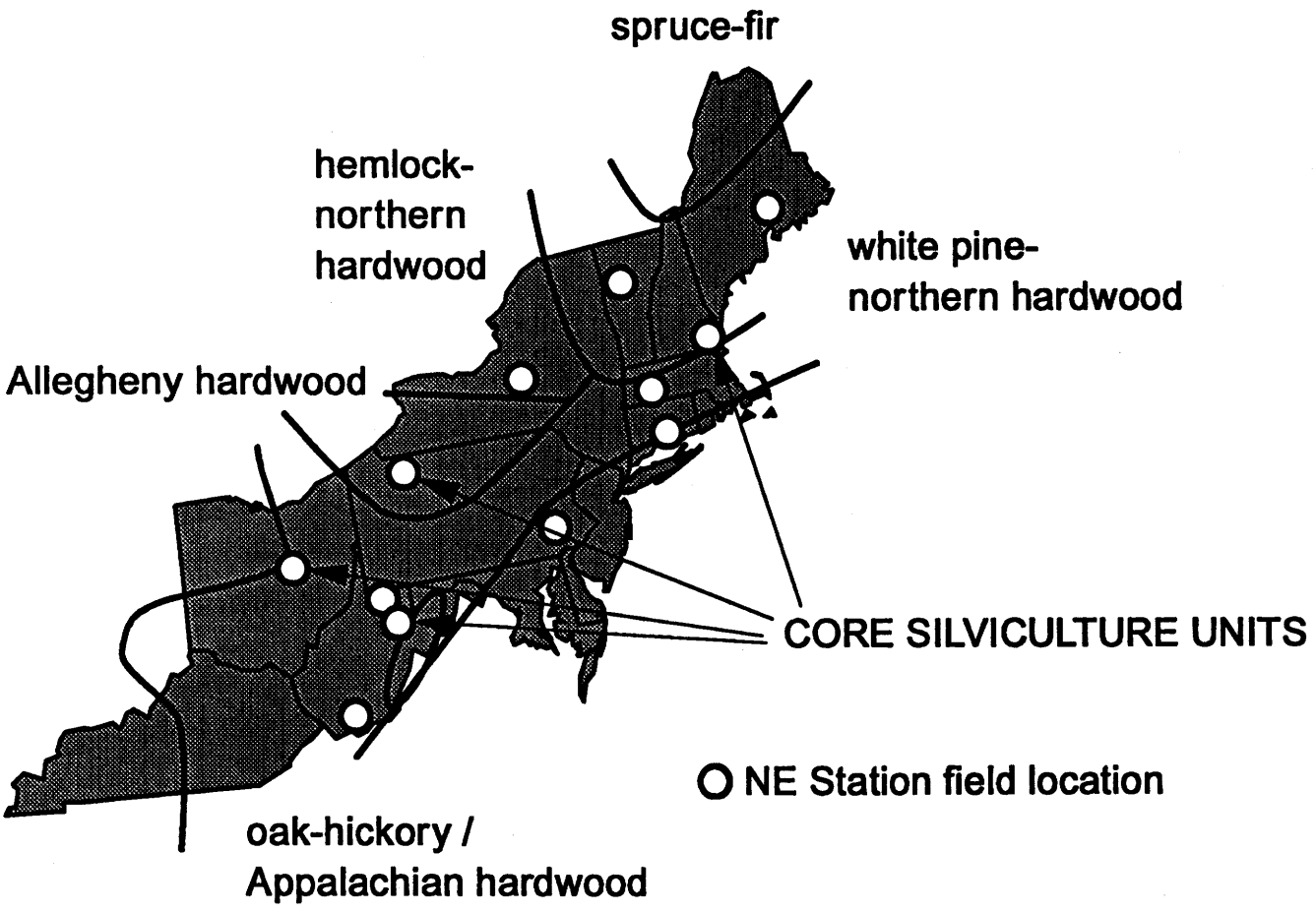

Figure 1.—Location of core silviculture research work units across the Northeastern Forest Experiment Station, with reference to associated major forest types.

selection—the harvesting of trees in small groups as contrasted with single-tree removals. Group selection concentrates the harvesting on groups of mature/ overmature trees, produces excellent regeneration in northern hardwood stands, and is acceptable to many NIPF's. Research continues on the effects of a broad range in group size on regeneration, productivity, and wildlife habitat, and the influence of site or landtype on group-selection dynamics (McClure and Lee 1992; Leak and Filip 1977).

Example No. 3.—Regenerating oaks on mesic sites is a widespread problem for forest managers throughout the eastern deciduous forest biome. Regeneration methods continue to be evaluated (Schuler and Miller 1995) and refined to achieve oak regeneration objectives (Schlesinger and others 1993, Loftis 1990). The Station is starting an oak regeneration initiative to coordinate efforts in this area. It will be concentrated within the oak-dominated forest types of Pennsylvania, Ohio, West Virginia, and Maryland. A portion of this area has suffered regeneration failures due to severe gypsy moth mortality, lack of advanced regeneration, overbrowsing by deer, invasion by exotic plants, other insects and pathogens, fire control, and lack of seed sources. We will develop techniques for rehabilitating these sites to restore oak-dominated forest ecosystems. Ecological site classification and other tools will continue to be used to help in the development of regeneration treatments. Natural (see Examples No. 4 and 5) and artificial (see Example No. 6) regeneration techniques will be developed. Cleanings and other precommercial silvicultural treatments will be investigated in relation to maintaining oak presence once regenerated (see Example No. 14). The goal of the research initiative is to develop guidelines for use in Eastern U.S. forests; therefore, treatments will need to be simple and cost-effective for them to be considered and implemented by NIPF landowners.

Example No. 4.—There is wide recognition that oaks are highly fire adapted, and that fire played a major role in the ecology of oak forests in the past, particularly in promoting the dominance of oak in regeneration layers. Fire has been absent from most of the oak-hickory type for most of this century. A study was recently initiated to determine the ecological response of mixed-oak communities in southern Ohio to prescribed underburning under fall and spring fire regimes. In addition to measuring tree regeneration response, the study aims to develop silvicultural tools for restoring the structure (fire adapted flora) and function to mixed-oak forests.

Example No. 5.—Regeneration practices that promote two-age stand structures have been applied as a viable alternative to clearcutting on national forests, state forests, and private forests in many eastern states. Similar to clearcutting, two-age regeneration treatments provide adequate light and seedbed conditions for the germination and development of numerous desirable hardwood species (Miller and Schuler 1995). However, this innovative silvicultural practice entails leaving a certain number of mature overstory trees per unit area in perpetuity to meet additional management objectives, particularly aesthetics and wildlife habitat. New research is needed to determine the growth patterns (for example, crown expansion rates) of the residual trees and the long-term effects of such factors on the developing reproduction. One such study is aimed at defining improved methods for increasing the proportion of oak regeneration that develops before and after two-age cuts are applied. This work includes shelterwood treatments to promote more competitive advance oak reproduction before two-age cuts and cleaning treatments to sustain saplings once they are established.

Example No. 6.—Natural regeneration methods for oak may require a lengthy period of time. An alternative regeneration technique being considered is the use of plastic tree shelters to protect seedlings from deer browsing and to stimulate juvenile height growth (Schuler and Miller 1996, Smith 1993). Tree shelters were developed in Europe and have been undergoing field trials since the late 1980's in the Eastern U.S. Station personnel have been leaders in determining the utility of tree shelters for differing silvicultural practices and land ownership preferences (Walters 1993, Smith 1993). Ongoing studies on both the Allegheny and Monongahela National Forest are evaluating the operational utility of shelters. Several long-term continuously monitored tree shelter studies are located on the Fernow Experimental Forest in West Virginia. The results from these efforts have led to the development of guidelines for tree-shelter use in establishing mesic-site oaks (Schuler and Miller 1996, Smith 1993). Continued research in this area is attempting to identify silvicultural treatments needed to maintain successfully established oak seedlings within the upper canopy stratum during the early stem exclusion stage.

Multiple Tangible Output Initiative

Historically, silvicultural research has focused on regeneration and wood production at the stand-level. Within the Station, long-term studies are being adapted to include additional non-commodity outputs within a hierarchy of spatial scales. And new studies are being installed to relate silvicultural practice to wildlife and wildlife habitat, aesthetics, old-growth (Nelson et al. 1997, this volume), forest health, riparian values, and the interactions among all these values.

Example No. 7.—In 1992, a 10-year research study was begun to determine the impacts of glyphosate and sulfometuron methyl on plants and wildlife in Allegheny hardwoods. The featured dependent variables in the study are herbaceous plants, small mammals, amphibians and songbirds. This research focuses on herbicide-shelterwood treatments, while a related administrative study focuses on the impact of herbicides in group selection treatments.

Example No. 8.—Research on the implications of two-age silviculture as an alternative regeneration method was initiated by Station scientists and land managers on the Monongahela National Forest in 1979 (Smith et al. 1989). Continuing silvicultural research is in progress to determine how the residual trees (density, structure, and species composition) affect the regeneration of eastern hardwoods and the production of multiple forest benefits such as aesthetics, species diversity, high-quality wood products, and habitat for wildlife species. For example, songbird density and nest success 10 years after clearcutting were compared with that observed 10 years after two-age cuts (Miller et al. 1995). Overall songbird density was greater in the two-aged stands, primarily as a result of the more diverse vertical structure of the residual stand. Other examples include comparisons of the aesthetics of two-age to other silvicultural treatments (Ping and Hollenhorst 1993) and evaluations of the immediate and long-term product market options of two-age systems compared to alternative management systems (Miller and Baumgras 1994) associated with perpetual two-age structures. As the application of two-age systems becomes more common, long-term data and experience gained from studying the early stage of two-age systems will play a vital role in answering new questions.

Example No. 9.—On the Kane Experimental Forest on the eastern edge of the Allegheny National Forest, a well-designed cleaning study was established in young Allegheny hardwoods in 1936. During the winter of 1996-97, we re-opened this study and remeasured tree and stand growth and development, including quality, to meet contemporary needs for information on young stand silviculture. Similar long-term studies of cleaning and weeding are being analyzed across the Station for northern hardwoods, transition oak, and oak-hickory.

Example No. 10.—Since the early 1950's, Station scientists have been evaluating effects of an array of silvicultural treatments on composition and structure of mixed northern conifers at the Penobscot Experimental Forest in east-central Maine. Even-age treatments in this replicated experiment include clearcutting and shelterwood. Selection stands in this study are the only examples of uneven-age silviculture in northern conifers in the Eastern U.S. Treatments also include diameter-limit cutting which, although not part of a silvicultural system, is a common practice in the region. Initial goals of the study were to determine how best to manage for financial returns and to determine if silviculture could reduce impacts of periodic spruce-budworm epidemics. As the treated stands developed, they also have been used to evaluate silvicultural effects on soils, wildlife habitat, insect diversity, coarse woody debris, and individual tree and stand growth efficiency.

Two recent publications demonstrate the value of this experiment to land managers. A financial analysis by Sendak and others (1996) indicated that the managed forest value is greater under selection silviculture than under even-age

systems. In an evaluation of the effects of intensity and frequency of harvesting on natural regeneration, Brissette (1996) showed that regardless of treatment, regeneration is prolific and dominated by balsam fir, hemlock, and spruce. However, a number of other species are well represented, providing managers with several options to meet future objectives. The value of these two analyses was substantially enhanced because of long-term databases available. This study has produced a diversity of stands with a range of species composition and structure, and interest in it for overlaying additional studies continues to grow.

Example No. 11.—Thinning regimes for Allegheny hardwoods were first developed in the mid-1970's using short-term field study results and computer simulations (Roach, 1977) and refined with longer term research (Marquis 1986, 1994; Ernst 1987; Marquis and Ernst 1991; Nowak 1996, 1997; Nowak and Marquis 1997). Many long-term field experiments on thinning are just now entering the end of the first cutting cycle, about 15 to 20 years after the initial cut. Thinning guidelines will continue to be refined using long-term results of these guidelines. A classic set of response variables will be featured in these studies, including wood production, tree stem quality, and understory vegetation response to changes in stand density, structure and species composition. A mechanistic approach will be used, for example, individual tree response will be related to crown architecture (see Nowak 1996) and other life history characteristics, and stand response will be related to plant succession and stage of stand development.

Example No. 12.—Silvicultural treatments can minimize gypsy moth damage to host hardwood stands. Decision charts were developed that match the proper prescription to existing stand and insect population conditions based on ecological and silvicultural information on forest-gypsy moth interactions (Gottschalk 1993). Some of these silvicultural treatments are currently being tested in several large research and demonstration studies with encouraging preliminary results. Use of silviculture to manage gypsy moth effects gives the forest manager tools other than chemical or biological insecticides for developing integrated pest management programs. Prescriptions for treatments take several approaches: reducing stand susceptibility and the probability of defoliation by changing species composition and gypsy moth habitat features; reducing stand vulnerability and the probability of mortality by removing trees most likely to die after defoliation (Gottschalk and MacFarlane 1993) and leaving trees more likely to survive and increase in vigor including regenerating stands in some cases; and treating stands after defoliation by salvage of dead trees, thinning of live trees to increase vigor and regenerating understocked stands.

Example No. 13.—Thirty-year results from a precommercial thinning study on the Bartlett Experimental Forest in a 25-year-old stand showed that fairly drastic treatments (for example, release of 400 crop trees/acre on all sides or complete removal of all weed trees) produced modest increases in tree diameter but had little effect on the species composition or structure of the stand (Leak and Smith, in press; Leak and Solomon, in press). Monitoring continues on the long-term effects of early thinning on quality development.

Example No. 14.—Thinning entails providing individual trees with added growing space by releasing their crowns, that is, removing adjacent trees whose crowns touch those of desirable crop trees. Such crown-release treatments have been studied in 7- to 80-year-old stands in the central Appalachian region since the 1960's. Results of these trials, formerly published in numerous separate reports, were synthesized and combined with new information from more recent studies (Miller, in press). Crown growing space, derived from the proportion of crown perimeter free-to-grow and distance to adjacent competing trees, is a significant independent variable that affects growth response. Crown growing space has a positive effect on d.b.h. growth and crown expansion and a negative effect on height growth and length of clear stem. The impact of crown growing space diminishes with tree age, though significant increases in d.b.h. growth were observed for 80-year-old trees. Additional research is needed to define how crown growing space affects other responses such as resistance to disease, longevity, and seed production. Applications of crown release treatments might be useful in sustaining certain individual trees for wildlife habitat and/or accelerating the development of certain stand attributes such as old-growth that are defined, in part, by tree size.

Example No. 15.—Truly integrated management of forest resources requires linking our understanding of wildlife habitat requirements to measured vegetative conditions. Using data from a series of operational- and research-scale study stands, scientists are refining thresholds for wildlife habitat in managed stands. In the short term, they will produce assessment tools for NED, a family of decision support software tools under development by the Station. Ultimately, researchers will develop silvicultural prescriptions to maintain, improve, or create habitat for specific wildlife.

Example No. 16.—Awareness of the importance of dead wood structures in forests has increased. The role of dead wood as habitat for wildlife and as foundation for many important processes such as regeneration and nutrient cycling is being investigated in many work units.

Intangible Outcome Initiative

The focus of silvicultural research is shifting from single and multiple value objectives to relationships among silvicultural activities and landscape-scale ecological balances, biological diversity, commodity production and other single forest value needs. Challenges for the future include expanding our mindsets from stands to landscapes, and from tangible, measurable outputs to intangible values that are more difficult to measure.

Example No. 17.—For more than 50 years we have recognized that deer impact is too high for many forest values on the Allegheny Plateau (Redding 1995), and that silviculture may be used to mitigate deer impact by manipulating deer forage-density-impact relations (Hough

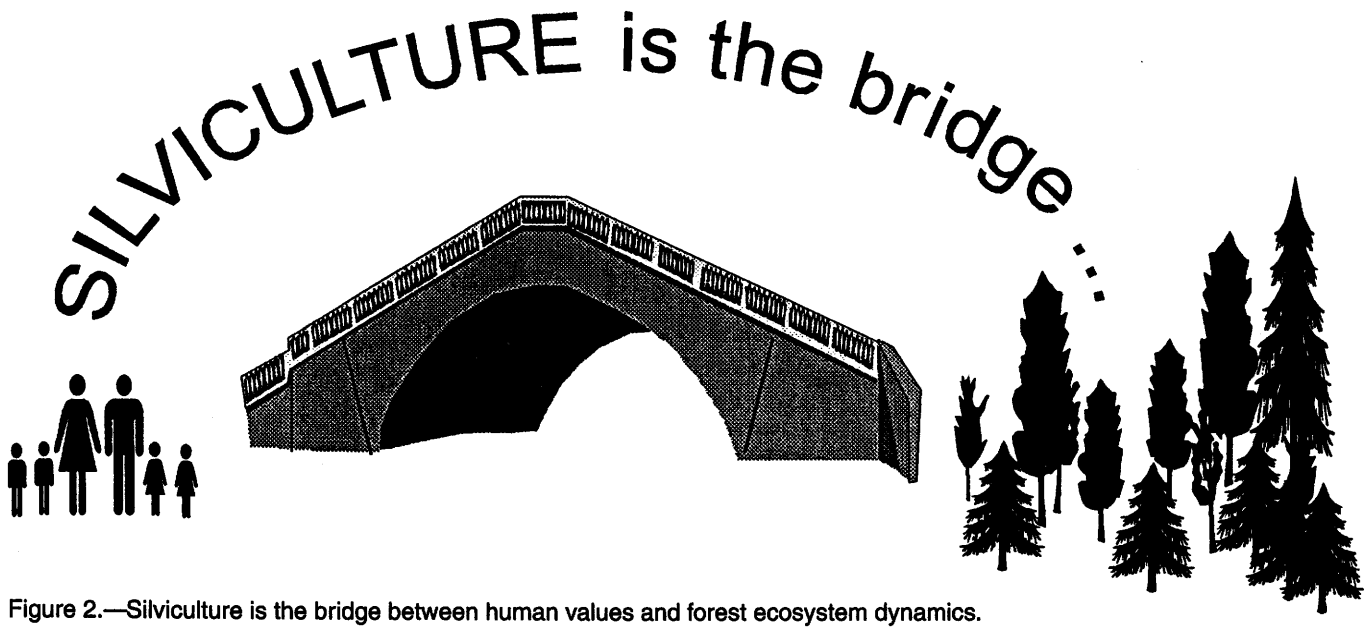

Figure 2.—Silviculture is the bridge between human values and forest ecosystem dynamics.

1953). Despite the long-term recognition of deer problems and attendant solution possible with silviculture, it is only with contemporary research (Stout et al. 1996; Stout and Lawrence 1996) that guidelines are being developed to specifically manage forest harvest areas and their spatial patterns to minimize the impacts of deer browsing on forest regeneration, wildlife habitat, and biological diversity.

Example No. 18.—Silvicultural research is moving from a preoccupation with stand-level responses to evaluation of silvicultural effects on species, structure, and wildlife habitat at the landscape level. Scientists recently completed an analysis of 60 years of data on the cumulative effects of management and natural disturbance (disease and wind damage) on species and structure across the Bartlett Experimental Forest. This analysis showed that natural succession (eastern hemlock dynamics particularly) was the primary influential factor—emphasizing the resilience of New England forests and their resilience to exogenous disturbance (Leak and Smith 1996). Similar examinations of long-term silviculture effects across ecosystems and landscapes are possible throughout the Station.

Example No. 19.—The effects of forest cutting on residual stand conditions have been examined across the State of Pennsylvania in two recent studies (McWilliams et al. 1995; Finley and Jones, in press; Nowak, in press). Future work should include more refined analysis of regeneration patterns across the Commonwealth and implications for sustainability, health, and productivity.

WHAT ARE THE LINKS TO THE OTHER EIGHT RESEARCH THEMES IN ROADMAP?

Silviculture is the bridge between human values and forest ecosystem dynamics (Fig. 2). Research provides the tools for managers to build that bridge.

As an integrating discipline, silvicultural research is viewed as the bridge between all of the more basic research themes (such as Basic Processes and Disturbance and Ecosystem Dynamics) and the social and economic dimension themes (such as Social and Economic Dimensions, and Forest Products, Production, and Use). This research is parallel to, and must be coordinated with, other management research themes (such as Inventory and Monitoring, Managing Forest Health, and Wildlife) and the other information integrating theme—Systems Modeling and Integration. The silvicultural theme integrates and translates more basic science information and information about societal needs into context for methods, guidelines, and models for managing forests. The approach for silvicultural and resource management research is focused on looking at the effects of manipulating vegetative communities. The nature of manipulation and variables for study are based on results from the more basic themes and customer needs. Study goals are built from social and human dimensions research. Research results from the themes in ROADMAP are the foundations and provide the biological and social sideboards for silviculture and resource management research and development.

The bridge analogy has been useful in communicating the role of silviculture and silvicultural research. It stresses the contribution of silvicultural research—developing practical options for sustainable management of forests—while building a critical relationship of silviculture to the other disciplines. As the other disciplines produce new knowledge, silvicultural researchers are poised to fashion that new information into useful and tangible resource management guidelines.

THIS IS A WORK IN PROGRESS ...

The key to a successful future role of silvicultural research is continued communication, continued redefinition of what silviculture research is and can be, and continued growth in

the relationship between silviculture and the other disciplines. A critical part of that communication is feedback from our stakeholders. We invite constructive criticism of this paper so that we can incorporate new ideas into our growing portrayal of silvicultural research in the Station.

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Two-Age Silviculture on the Monongahela National Forest—Managers and Scientists Assess 17 Years of Communication

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Abstract.—This report describes the development of two-age silviculture on the Monongahela National Forest and provides an assessment of the practice as it is applied today. Silviculturists at each ranger district provided a chronology of the communication process between managers and scientists that led to current stand treatment prescriptions. In addition, data were collected from a total of 20 recently treated stands on four ranger districts. This information was used to assess two-age systems in terms of current stand conditions and the implications for future species composition and stand structure. Comments obtained from land managers and the accompanying field data are used to illustrate how the ongoing communication process helped to provide feedback, clarify objectives, motivate useful research, define feasible options, and produce a flexible land management tool.

INTRODUCTION

For many years, clearcutting was an important silvicultural practice for harvesting and regenerating new stands of central Appalachian hardwoods on the Monongahela National Forest (MNF). Public opposition to the visual impacts of clearcutting led land managers to seek alternatives that provide adequate light and seedbed conditions for tree regeneration, but are more aesthetic after cutting while the new stand becomes established (Smith and others 1989). Since 1991, clearcutting has been prescribed on a decreasing number of acres on the MNF and is being replaced in part by two-age silvicultural systems, alternative regeneration methods that show promise in sustaining multiple forest benefits such as aesthetics, species diversity, high-quality wood products, and habitat for many wildlife species.

This paper describes an ongoing partnership between land managers on the MNF and scientists at the Northeastern Forest Experiment Station (NEFES) that led to the expanded use of two-age silvicultural systems to meet emerging management objectives. First, background information is provided to clarify silviculture terminology and to chronicle the history of two-age silviculture as it has been applied on the MNF. Second, the process of communication between managers and scientists is summarized to demonstrate a possible model for others to use in developing and implementing innovative silvicultural practices. Third, results from a recent study of 20 two-aged stands located throughout the MNF are provided to illustrate the current status of this practice in three forest cover types.

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BACKGROUND

Two-aged stands resemble those treated with a seed-tree or shelterwood practice in that a given number of overstory trees are retained while all other trees are cut (Fig. 1). However, to maintain a two-age stand structure, the residual trees are not cut once the reproduction becomes established as in even-age practices. Instead, the harvest of the residual trees is deferred until new reproduction is between 40 and 80 years old, generally one-half to a full sawtimber rotation. The result is a two-age stand structure. Once the two-age stand structure is established, similar practices can be repeated at intervals of 40 to 80 years to maintain this condition for many years. Management of some stands on the MNF is based on a 200-year rotation, so two-age cuts could be applied several times per rotation.

Silviculturists use several terms to describe regeneration methods that effectively create a two-age stand structure. These terms include deferment cutting, clearcutting with reserves, shelterwood with reserves, and irregular shelterwood. Deferment cutting and clearcutting with reserves are used to describe practices in which residual trees are retained for an entire sawtimber rotation to achieve goals other than reproduction. The other terms describe practices in which residual trees are retained to achieve goals other than regeneration, but not necessarily for an entire rotation. Thus, the terms used to describe two-age regeneration methods are defined by how long the residual trees are to be retained. In practice, residual trees can be retained for different periods of time to achieve different goals. For this reason, two-age silviculture is a general term that describes a host of regeneration methods designed to maintain and regenerate a stand composed of two distinct age classes that are separated by more than 20 percent of the planned rotation.

Silvicultural systems that promote a two-age stand structure have been initiated on national forests, state forests, industrial forests, and to a lesser degree on nonindustrial private forests in many eastern states. A similar practice called "insurance silviculture" was applied in Pennsylvania to retain a seed source in the event of a regeneration failure (Bennett and Armstrong 1981). The reasons for using two-age silvicultural methods are twofold: to regenerate a variety of species, particularly those that are shade-intolerant, and to mitigate the perceived negative visual impacts of clearcutting. Similar to clearcut stands, natural regeneration that follows two-age regeneration methods includes a variety of both shade-tolerant and shade-intolerant commercial hardwoods (Trimble 1973; Miller and Schuler 1995). Unlike

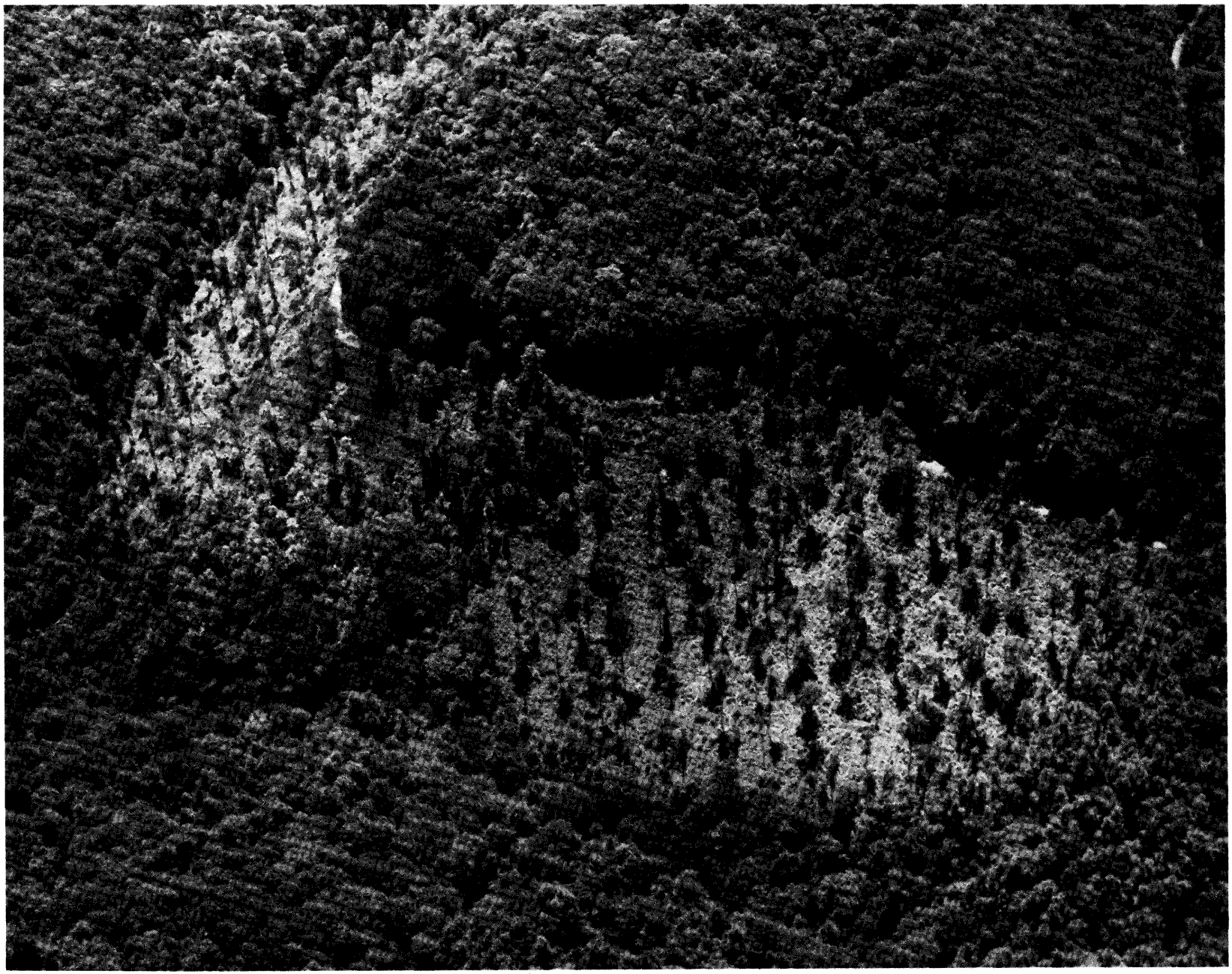

Figure 1.—A two-aged central Appalachian hardwood stand 3 years after treatment.

clearcutting, however, the presence of residual overstory trees improves aesthetics and maintains a more diverse vertical stand structure that may benefit certain wildlife species (Pings and Hollenhorst 1993). As the new cohort develops beneath the large overstory residuals, the stand has two distinct height strata. These strata provide a diverse habitat for songbirds that forage in high canopy trees (Wood and Nichols 1995), as well as those that require a brushy cover characteristic of a young even-aged stand (DeGraaf and others 1991). Two-age silvicultural practices also provide an opportunity to retain species that produce hard mast for wildlife food.

Early History

During the 1970's, forest managers on the MNF began considering alternative regeneration methods in response to public criticism of clearcutting. An employee of the USDA Forest Service visited Europe and learned of deferment cutting, a two-age regeneration practice used to manage larch, pine, and oak-beech stands (Kostler 1956; Troup 1966) to improve the aesthetics of even-age practices that remove the overstory over a relatively short interval. In 1979, an experimental deferment cut was applied on the Greenbrier Ranger District in cooperation with NEFES scientists at Parsons, West Virginia. Five additional experimental deferment cuts were applied on the Cheat and Marlinton Ranger Districts and the Fernow Experimental Forest by 1983. These study sites, which range from 10 to 15 acres, have since provided preliminary silvicultural information on two-age regeneration methods for forest managers who are interested in alternatives to clearcutting.

After the experimental deferment cuts were applied, the study sites served as valuable demonstration areas where students and forest managers from the forest industry and various public agencies were able to see two-age silviculture in action. As these two-aged stands developed through the 1980's, preliminary reports were published on residual tree growth and the development of regeneration (Beck 1986; Smith 1988; Smith and others 1989). In addition, forest managers on the MNF were able to visit these stands over the course of several growing seasons to monitor the progress of the new reproduction and to evaluate their potential as an alternative to clearcutting.

Recent History

In 1990, a team was organized on the MNF to define and evaluate possible alternatives to clearcutting. This team included experts from many disciplines: wildlife biology, landscape architecture, silviculture, and forestry research. Two-age management was included as a viable alternative for regenerating shade-intolerant species and improving aesthetics. The first operational two-age cuts were applied on the Potomac and Greenbrier Ranger Districts in 1991. These stands also served as demonstration areas for managers from other districts.

Since then, clearcutting has been prescribed on a decreasing number of acres. Since 1990, regeneration treatments were prescribed on an average of 1,500 acres/year on the MNF. The proportion of acres on which clearcutting was prescribed declined from 98 to 45 percent from 1990 to 1995. In most situations, two-age regeneration treatments were prescribed instead of clearcutting, and this trend is expected to continue.

In 1995, personnel from the MNF, NEFES (Parsons, WV), and Northeastern Area State and Private Forestry (Morgantown, WV) collaborated on a Marker Training Workshop for timber marking crews on the MNF. Silviculturists and marking crews from each district attended a 2-day training session that focused on proper residual stand stocking levels and criteria for identifying leave-trees to meet various management objectives. This workshop included hands-on marking exercises in various forest cover types. An important result of this workshop was that the concerns of district silviculturists, specialists from non-timber disciplines, and administrators on the forest were included in the marking guidelines. As a result, timber marking became more consistent throughout the forest, and marking crews were better prepared to implement the intended prescriptions.

The process of evaluating two-age practices and improving application methods on the MNF is continuing. The aesthetics of residual stands were compared to those resulting from other silvicultural methods (Pings and Hollenhorst 1993). A study of songbird density and nesting success in two-aged stands was conducted from 1992-1996 (Wood and Nichols 1995; Miller and others 1995). Logging economics and product market options also have been investigated (Miller and Baumgras 1994; Baumgras and others 1995). New studies are planned to develop improved methods for increasing the proportion of oak regeneration that develops before and after two-age cuts are applied.

COMMUNICATIONS

The following sections describe highlights in the ongoing partnership between land managers and scientists that led to increased use of two-age silviculture as an alternative to clearcutting on the MNF. The first two sections describe how management objectives and stand treatment prescriptions evolved during this process, followed by recommendations from forest managers for future research needed to improve the effectiveness of two-age regeneration methods. Finally, some suggestions on useful communication tools are offered that might assist other forest management partners in developing and implementing innovative silvicultural practices.

Defining Forest Management Objectives

An important first step in the development of two-age silviculture on the MNF was to narrowly define the problem and to clarify the management objectives so that specialists from a variety of resource management disciplines could work toward a common end. Initially, the problem was defined as the need for practical alternatives to clearcutting. The objectives were to identify alternative regeneration methods that provide for adequate desirable regeneration after harvest operations and improve the aesthetics of treated stands compared to clearcutting.

A range of regeneration methods was evaluated based on their effectiveness in providing the light and seedbed conditions necessary to regenerate desirable species, while improving the post-harvest aesthetics compared to clearcutting. In evaluating potential alternatives, additional management objectives became apparent. For example, group selection, which results in small clearings (0.5-2.0 acres) where desirable regeneration can develop and aesthetics are improved compared to clearcutting, is a viable alternative. However, this alternative would require a dramatic increase in the number of sale acres to regenerate the same number of acres as would be possible through clearcutting. Another objective for alternative harvest methods called for silvicultural practices that would not involve sale acres beyond practical limits. While group selection is a sound silvicultural practice, other regeneration methods (in addition to group selection) were needed to address concerns about sale acreage.

The implications for wildlife habitat also were considered in evaluating potential alternatives to clearcutting. Several options such as seed tree, shelterwood, and two-age practices, which entail the retention of residual trees, were recognized as improvements over clearcutting because residual trees provide mast, dens, perches, and habitat for foraging and nesting for many wildlife species. Moreover, two-age practices were superior because residual trees are retained for a relatively long time compared to seed tree and shelterwood practices. As a result, improved wildlife habitat also emerged as one of the management objectives used to define suitable alternative harvest methods.

As resource management specialists and scientists worked toward defining a suitable alternative to clearcutting, various silvicultural options also were evaluated in terms of their potential effect on Forest Plan goals and management prescriptions. For example, each alternative was evaluated in terms of its effect on recreation, aesthetics, harvest volumes and acreages, and economics. The interaction among the various resource specialists, scientists, and administrators that occurred during this process resulted in a valuable exchange of ideas and a more integrated approach to land management that continues today. Through this process, land managers at the district level became better prepared to prescribe stand treatments that account for many management objectives involving multiple forest resources.

Stand Prescriptions Then and Now

Based on information provided by forest managers at each of the ranger districts, stand prescriptions for two-age regeneration methods have changed since 1991 as individual silviculturists build on their experience with this relatively new practice. The initial prescriptions called for residual basal areas ranging from 20 to 40 ft^2/acre, with the residual stand composed of mostly sawtimber trees (Smith and Miller 1991). Actual residual stocking levels after harvest operations were greater than intended because marking crews were accustomed to leaving more trees as is done in thinnings or selection cuttings. There also was a tendency to remove most of the larger, high-quality sawtimber and retain the smaller, low-quality sawtimber and poletimber. This was due in part to the perceived risk of grade loss, logging damage, or grade reductions from epicormic branching to residual trees during and after harvest operations.

As silviculturists and marking crews on the districts gained more experience with this practice, and additional information about the response of residual trees was provided by scientists, stand prescriptions have changed accordingly. In general, the more recent stand presciptions reflect an increased emphasis on enhancing the long-term species composition of the regeneration and quality of the residual trees. More recent prescriptions require lower residual stand density, ranging from 20 to 30 ft^2/acre with about 15 to 20 sawtimber trees/acre. These prescriptions also call for cutting all other stems 1.0-inch d.b.h. and larger. Lower residual densities are more favorable to the reproduction of desirable shade-intolerant species, particularly over long periods of time when crown expansion of residual trees may interfere with reproduction. Current prescriptions also call for leaving larger, high-quality, long-lived sawtimber trees because vigorous codominant trees are less likely to die or suffer grade loss after treatment than trees in weaker crown positions (Miller 1996).

Guidelines for choosing residual trees to improve wildlife habitat also have improved as forest managers gain experience with two-age regeneration methods. This improvement is the result of continued interaction among personnel of several resource disciplines, since the first two-age cuts were applied on an experimental basis in 1979. Desirable residual trees for mast production include American beech, black gum, hickory, and the oaks. For example, white oaks are preferred residual trees for wildlife and timber because they are long-lived and produce acorns for a relatively long time. For habitat diversity, residual trees also include cull trees with large cavities, standing dead trees, and conifers such as hemlock, pines, and spruces.

Research Results and Future Needs

Two-age regeneration practices were applied on an experimental basis in six central Appalachian hardwood stands on the MNF and the Fernow Experimental Forest from 1979 to 1983. These areas ranged from 10 to 15 acres on site index 70 and 80 for northern red oak and provided preliminary results on the growth and development of the residual overstory trees and the species composition and quality of reproduction that became established after the treatments were applied. Such results were shared with silviculturists on the MNF over the years and later published. The following sections provide a brief review of research results that were helpful in developing stand prescriptions in use today, followed by a summary of new research that forest managers need for the future.

A Review of Research Results

D.b.h. Growth.—In general, residual trees after two-age regeneration harvests exhibited faster diameter growth compared to control trees in uncut stands over the 10-year

study period, though growth response varied by individual species (Miller and others 1995) (Table 1). Residual trees were free-to-grow with an average crown growing space of 20 feet to adjacent residual tree crowns after treatment (Miller and Schuler 1995). Control trees also were codominant, but they had crown competition on all sides during the study period. For black cherry, average d.b.h growth of untreated controls exceeded that of released trees, though the difference was not statistically significant (P = 0.48). For all other species tested, released trees had greater average d.b.h. growth compared to that for control trees.

D.b.h. growth of released trees was 45 to 134 percent faster than controls, led by white oak, yellow-poplar, basswood, and red oak. White oak, chestnut oak, red oak, and basswood grew faster the second 5 years compared to the first 5 years after treatment. For yellow-poplar, residual trees grew faster during the first 5 years after treatment, though growth during the second 5 years continued to exceed that of controls.

Table 1.—Ten-year d.b.h. growth for central Appalachian hardwoods released by deferment cutting versus unreleased controls

Species	Treatment	Number of trees	Initial d.b.h.	10-year d.b.h. growth	P[a]
			Inches		
White oak	Release	59	14.5	2.89	<0.01
	Control	14	19.6	1.02	
Chestnut oak	Release	12	14.4	2.18	0.13
	Control	6	17.2	1.57	
Red oak	Release	200	16.7	3.34	<0.01
	Control	58	19.9	1.92	
Yellow-poplar	Release	193	17.8	3.65	<0.01
	Control	46	17.3	1.95	
Black cherry	Release	66	14.2	2.30	0.48
	Control	47	16.9	2.21	
Basswood	Release	18	15.1	2.93	<0.01
	Control	9	18.6	1.47	

[a]P= probability of a larger F for 10-year growth; analysis of covariance means adjusted for initial dbh.

Survival and Quality of Residual Trees.—A total of 667 residual trees were monitored for survival and quality after two-age cuts were applied (Miller 1996). After 10 years, 89 percent of residual trees had survived. A total of 6 trees (1 percent) were destroyed or removed due to inadvertent damage during logging. After logging, 22 trees (3 percent) died within 2 years, and an additional 38 trees (6 percent) died between the 2nd and the 5th year. Mortality after the 5th year was greatly reduced; only an additional 7 trees (1 percent) died by the end of the 10th year. Mortality was greatest for black cherry (more than 20 percent), least for yellow-poplar (less than 5 percent).

The risk of residual trees developing new epicormic branches increases as the intensity of the cut increases (Trimble and Seegrist 1973). Epicormic branching increased for all species within 2 years after two-age cuts compared to pretreatment levels. Between year 2 and 10 there was no significant increase in the number of epicormic branches on the butt 16-foot log sections. Epicormics continued to increase on the second 16-foot log section for black cherry, red oak, and yellow-poplar. The net effect on quality was that 12 percent of residual trees exhibited a reduction in grade (Hanks 1976) due to new epicormic branches over the 10-year study period. Of the few grade reductions observed, white oak, northern red oak, and black cherry were most susceptible, while less than 1 percent of yellow-poplar trees had lower grades due to epicormic branching.

Logging operations resulted in bark wounds (exposed sapwood) on about one-third of residual deferment trees. Half of wounded trees had wounds less than 50 in^2, and half had larger wounds. Most of the wounds were located on the lower portions of the bole and were caused by skidding logs too close to residual trees. More than 95 percent of logging wounds that were less than 50 in^2 in size callused over and were closed within 10 years after logging. Based on the observed rate of closing over a 10-year period, Smith and others (1994) estimate that larger wounds up to 200 in^2 in size will close within 15 to 20 years after logging.

Reproduction.—Reproduction observed after two-age cuts was similar to that observed after clearcutting (Miller and Schuler 1995). Before two-age cuts were applied, small reproduction (less than 1.0 inch d.b.h.) averaged 3,019 stems/acre, with 50 percent in shade-tolerant species (maples and American beech), 37 percent in shade-intolerant species (black cherry and yellow-poplar), and 13 percent in intermediate-shade-tolerant species (oaks and white ash). More than 80 percent of survey plots (0.001-acre) had at least one commercial hardwood species present, and more than 60 percent of survey plots had sugar maple or American beech present.

Two years after harvest, small reproduction (< 1.0 inch d.b.h.) in the study areas averaged 9,100 stems/acre of commercial species composed of 60 percent seedling-origin stems. There also were more than 14,000 stems/acre of noncommercial woody species. More than 95 percent of survey plots had a commercial stem present. Five years after harvest, the canopy of the new age class developing beneath the residual overstory had not closed. Large woody

reproduction (≥ 1.0 inch d.b.h.) after 5 years included more than 300 stems/acre of commercial species and 100 stems/acre of noncommercial species.

After 10 years, the canopy of the new age class developing beneath the deferment trees was nearly closed, and codominant trees averaged 35 feet tall. Large reproduction included 991 stems/acre of commercial species, with 450 good, codominant stems/acre exhibiting the potential to become high-quality crop trees in the future. On excellent growing sites, northern red oak reproduction was sparse, averaging only 10 potential crop trees/acre. Other codominant, commercial species reproduction included a variety of both shade-tolerant and shade-intolerant species distributed over 74 percent of the stand area.

Songbird Density and Nest Success.—Songbird density and nest success in clearcut and two-aged stands were compared 10 years after cutting treatment (Miller and others 1995; Wood and Nichols 1995). Songbird density estimates were greater (649 vs. 522 birds/ 40 ha; $P < 0.001$) in the two-aged stands. Interior-edge (359 vs. 320 birds/40 ha; $P<0.001$) and edge (83 v. 12 birds/40 ha; $P<0.001$) species were more abundant in two-aged stands. The abundance of interior species was similar (207 vs. 190 birds/40 ha; $P >0.10$) for two-aged and clearcut stands, respectively. Nest survival (151 nests) was not significantly different between the two-age and clearcut treatments (50% vs. 54%; $P>0.10$), and predation by mammals was the most common cause of nest failure.

Future Research Needs

As silviculturists on the MNF gained experience in prescribing two-age regeneration treatments and considered the implications of such practices for the future, the following questions arose.

Harvesting systems and economics.—For unconventional logging operations based on cable and helicopter systems, what is the optimal pattern of residual trees to minimize logging cost and damage to residual trees? How do local markets influence the cutting cycle and product mix for harvests in two-aged stands? How can two-age regeneration methods be applied in stands where there is limited merchantable volume and value?

Regeneration.—How does residual stand density and structure affect species composition and quality in the future? What silvicultural treatments are needed before two-age cuts are applied to increase the reproduction of target species such as northern red oak? How does the logging system and season of logging operations affect reproduction? What impact do residual trees have on the genetics of reproduction in the future? What impact do deer have on reproduction?

Residual trees.—How does increased diameter growth affect tree quality for veneer products? How do logging wounds affect the quality and vigor of residual trees? How do tree age and species affect growth, survival, and seed production? What is the rate of crown expansion for residual trees of different species?

Non-timber Issues.—How do two-age stand structures affect aesthetics in middle-ground views (0.25-4 miles)? How do residual tree species, vertical structure, and density affect aesthetics? How do aesthetics change as the new stand develops and vertical structure becomes more diverse? How do residual stand structure and density affect songbirds, small mammals, and game species over time?

As two-age regeneration methods are used to meet emerging forest management objectives, additional research is needed to better understand the implications of this innovative practice. It is important to define linkages among abiotic and biotic ecosystem components that may be affected by maintaining two vertical strata of woody vegetation over extended periods of time. For example, additional studies are needed to determine the relationship between stand density and structure on game and nongame wildlife communities. And because the forest is always changing, more research is needed to define the susceptibility of residual trees to attacks by insects and pathogens over much longer time periods. This practice may also affect product options in the future. Residual trees grow rapidly after two-age regeneration cuts, and such growth rates may influence product quality and utilization options.

Suggested Communication Tools

Land managers and scientists utilized several communication tools during the last 17 years to improve and develop two-age stand management prescriptions. The following suggestions are four possible strategies that might be helpful to others who are considering the use of unconventional silvicultural methods: the use of demonstration areas, holding meetings in the field, conducting forest-wide training sessions, and sharing preliminary information.

The stands in which experimental two-age cuts were applied served as valuable demonstration areas for sharing information. Initially, forest managers had the opportunity to evaluate the general appearance of a two-aged stand and ask important questions about the long-term implications of such treatments. The initial visits prompted numerous questions about the fate of residual trees and the new reproduction. As a result, the demonstration areas challenged land managers and scientists to better understand the implications of two-aged stands. As the stands developed, these areas also provided a medium for presenting and interpreting preliminary results.

The demonstration areas were located throughout the forest on three ranger districts, so forest management personnel had "ownership" and were able to visit these areas and monitor development with minimal investment of time and expense. Later, these areas served as a place to hold meetings, train personnel, and educate the public about the objectives of two-age silviculture. Thus, it is important that demonstration areas are accessible and inexpensive to visit for maximum impact on communications.

Another successful communication strategy entailed holding meetings among resource specialists, district silviculturists,

and the forest leadership team in the field, against the backdrop of one or more of the demonstration areas. These sessions were two-way exchanges of questions and answers for personnel at different levels of management. The outdoor forum promoted an open dialog of ideas and reduced confusion about the management objectives and/or the long-term implications of using two-age regeneration methods. In particular, such meetings were an efficient use of time because participants usually could direct their questions and answers to tangible issues such as epicormic branching on residual trees, characteristics of forest roads, or vertical structure of the residual stand that are visible on the site. In addition, scientists often were invited to such meetings to provide updated research results and to stay abreast of new research needs.

Table 2.—Percent of trees reduced in grade due to logging wounds or epicormic branching after deferment cutting[a]

Species	Small sawtimber (12-16 inches d.b.h.)				Large sawtimber (18 inches d.b.h. and larger)			
	n	Number of trees	%	95% CI[b]	n	Number of trees	%	95% CI
Yellow-poplar	23	1	4	<1-34	11	0	0	0-46
Black cherry	59	3	5	<1-11	38	3	8	1-22
Northern red oak	43	2	5	<1-19	32	1	3	<1-16
White oak	19	0	0	0-20	9	1	11	<1-48
Chestnut oak	22	0	0	0-11	15	0	0	0-33
Sugar maple	61	4	7	<1-12	20	0	0	0-17
Red maple	49	1	2	<1-12	10	0	0	0-49
White ash	41	4	10	<1-18	20	0	0	0-17
American basswood	17	0	0	0-26	3	0	0	0-71

[a]Data from 20 stands on the MNF where operational two-age cutting was applied.
[b]95% confidence interval.

The forest-wide training for marking crews helped to make two-age stand treatment prescriptions more consistent across the forest. Marking crews and silviculturists from all districts had the opportunity to interact with each other through hands-on marking exercises in the field. Participants practiced selecting residual trees, asked questions of each other, and resolved confusion about management objectives associated with two-age systems. These activities clarified the criteria for selecting residual trees for a range of objectives. As a result, the 2-day training session prepared each marking crew to better implement a stand prescription as intended by the silviculturist.

Scientists also made an effort to share preliminary research information with land managers as it became available. This was accomplished through preliminary written reports (before the formal publication of results), telephone conversations, and field visits to the demonstration areas. Obtaining preliminary research results at frequent intervals helped the silviculturists make more rapid progress toward developing appropriate stand prescriptions. Similarly, presenting such information and obtaining feedback helped the scientists focus on the high-priority needs of the land manager. This exchange of preliminary information is ongoing.

There also are opportunities to communicate the implications of innovative silvicultural practices through existing channels within the Forest Service. For example, two-age silviculture is now part of the Program of Advanced Studies in Silviculture (PASS) throughout Regions 8 and 9. At the forest level, the forest planning process provides an opportunity to involve outside groups in fine-tuning the objectives of silvicultural treatments, which in turn clarifies guidelines for writing stand treatment prescriptions.

ASSESSMENT OF CURRENT PRACTICES

In 1996, data were collected on 20 two-aged stands on the MNF that had been treated two to five growing seasons before the study. This survey was conducted to assess current conditions and to shed light on the implications of two-age cutting on future species composition and wood product quality. Thus, the results presented here on residual tree response and reproduction are preliminary findings that do not necessarily represent the long-term implications of this practice (Johnson and others 1997).

Residual stand quality

A total of 768 individual trees representing nine commercial species were evaluated for tree grade (Hanks 1976), epicormic branches, and logging damage. In general, deferment cutting did not result in significant changes in grade distributions in the first 2 to 5 years after treatment. Among large sawtimber (17.0 inches d.b.h. and larger), 11, 8, and 3 percent of white oak, black cherry, and northern red oak, respectively, exhibited grade reductions due to logging wounds or epicormic branches. Large sawtimber of other species did not exhibit grade reductions. Among small sawtimber (11.0 to 16.9 inches d.b.h.), grade reductions were more common compared to those for large sawtimber (Table 2). The development of epicormic branches was most prevalent on white oak. Suppressed and intermediate trees developed more epicormic branches and had more reductions in tree grade compared to those for codominant and dominant trees. In all of the 20 stands, logging wounds were found on 45 percent of residual trees, and 21 percent of trees had severe wounds larger than 100 in^2. However, the number of trees wounded and the severity of wounds were related to the months in which logging occurred (Fig. 2). Logging damage was greatest during the spring (March-June) and least during the dormant season (November-February). The data indicate that logging damage can be reduced by 50 percent if operations are conducted in the fall and early winter months.

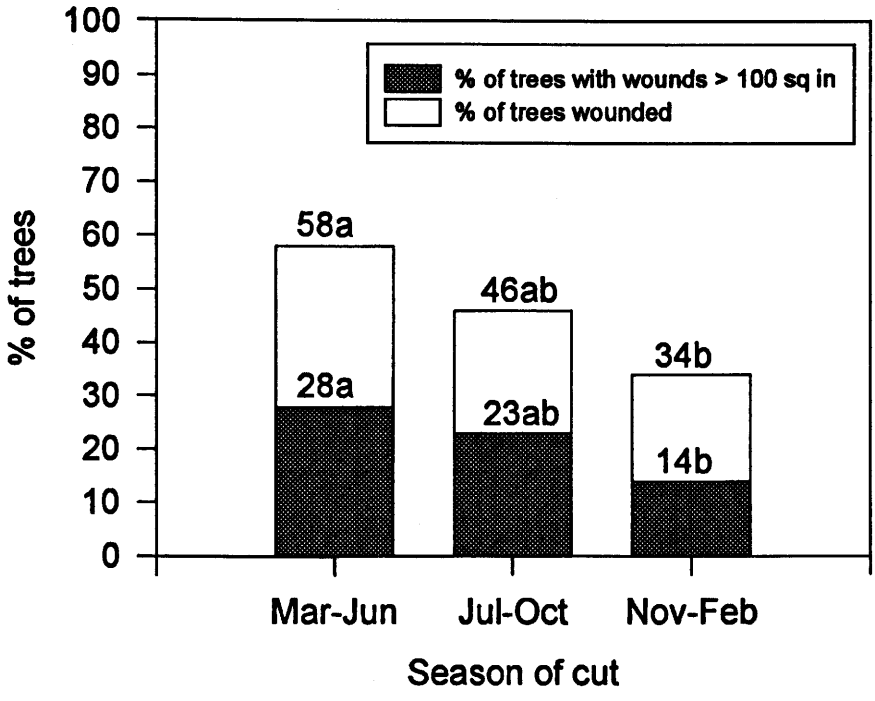

Figure 2.—Mean percent of residual trees with logging wounds. For bars of the same shade, means followed by the same letters are not significantly different at the 0.10 level based on analysis of variance followed by Tukey HSD.

Regeneration

Very small (< 1.0 ft tall) and small (≥ 1.0 ft tall and < 1.0-inch d.b.h.) reproduction was tallied within 1/1,000-acre circular plots, and large reproduction (1.0-inch d.b.h. and larger) was tallied within 1/100-acre circular plots. From 25 to 50 reproduction plots were located along systematic grids within each stand. For very small and small reproduction, stem counts and heights were recorded for each stem observed on a plot. For large reproduction, species, d.b.h., stem origin, quality, and crown class were recorded for each stem observed on a plot.

Stands were grouped by three forest cover types before regeneration results were summarized: beech-cherry-maple at the higher elevations in the Allegheny mountains, mixed Appalachian hardwoods in the coves of the Allegheny Mountains, and mixed oaks in the Ridge and Valley province east of the Allegheny Front. Most of the reproduction present on the survey plots was less than 1.0 ft tall (Table 3). In the beech-cherry-maple stands, reproduction was dominated by American beech, black cherry, and the birches, though many other species also were present. The mixed Appalachian hardwood stands contained the greatest diversity of species, though birches, maples, black cherry, and white ash were most abundant. Reproduction in the mixed-oak stands was dominated by red and sugar maple, birches, and northern red oak, though oak reproduction is difficult to sustain on high-quality growing sites. These results are consistent with other studies of two-age and even-age regeneration practices (Trimble 1973; Miller and Schuler 1995; Beck 1986).

The total number of noncommercial stems was relatively small, representing only 5, 12, and 28 percent of stems present in the beech-cherry-maple, mixed Appalachian hardwood, and mixed oak cover types, respectively. Noncommercial stems included striped maple, dogwood, pin cherry, sassafras, serviceberry, and American hornbeam. These stems are not expected to interfere with the growth and development of commercial species (Miller and Schuler 1995).

As these stands continue to develop, the trees in the new age class will form a height stratum distinct from the larger overstory trees left after logging. Stems present when data were collected will compete for crown position until the canopy of the new age class closes from 10 to 15 years after logging. At this point, most areas have adequate density and distribution of desirable reproduction. However, it is too soon to predict the eventual species composition. Trees that attain a codominant position at crown closure will determine the species composition of these stands for many years to come. Soon after crown closure, preferred crop trees can be given a crown release to assure their survival and competitive position within the stand.

Summary of Results

Results of this study were evaluated by land managers on the MNF and the following preliminary conclusions were drawn:

- Two-age silvicultural systems met the goals for timber, many wildlife species, and aesthetics.
- Residual basal area averaged 39 ft²/acre; 82 percent of residual trees met timber objectives.
- Residual stands contained a mix of species, and 64 percent of residual trees were considered to be low-risk—expected to live more than 20 years after treatment.
- Only 8 percent of residual trees had died or blown over 2 to 4 years after treatment.
- Tree grades were not seriously reduced after treatment.
- The average size of logging wounds and the proportion of trees wounded was greatest for operations conducted from March through June, least from November through February.
- Regeneration was similar in composition and abundance to that observed after clearcutting.

DISCUSSION

Experience with two-age cutting since 1979 indicates that desirable reproduction can be established and will develop into an acceptable new crop for sustained production of

Table 3.—Summary of reproduction present 2-5 years after deferment cutting by forest cover type

Species	Beech-Cherry-Maple		Mixed Appalachian Hdwds		Mixed oaks	
	Very small[a]	Small[b]	Very small	Small	Very small	Small
	Number of stems/acre (% of plots stocked)					
Birches[c]	8,464(62)	1,989(31)	3,502(39)	2,324(24)	2,886(25)	137(9)
Maples	1,717(50)	641(16)	1,116(39)	516(19)	2,259(50)	556(14)
Red oaks	9(1)	3(1)	410(24)	203(11)	582(18)	100(7)
White oaks	0(0)	0(0)	80(8)	254(1)	103(6)	140(3)
Am. beech	2,268(55)	4,591(63)	83(4)	162(4)	20(1)	0(0)
Black cherry	6,357(68)	3,825(44)	820(25)	466(14)	40(2)	45(2)
Hemlock	68(3)	0(0)	0(0)	4(1)	0(0)	0(0)
White ash	38(3)	30(1)	829(22)	499(12)	30(30)	0(0)
Yellow-poplar	404(12)	70(4)	3,271(35)	62(3)	367(13)	18(2)
Am. basswood	0(0)	0(0)	4(1)	12(1)	0(0)	0(0)
Others	305(16)	68(5)	185(14)	396(17)	299(16)	520(20)
Total[d]	19,628	11,217	10,300	4,898	6,586	1,516

[a]Very small reproduction = all stems < 1.0 ft in height
[b]Small reproduction = stems ≥ 1.0 ft in height and < 1.0 inch dbh.
[c]Birches include sweet and yellow birch; maples include red and sugar maple; red oaks include northern red, scarlet, and black oak; white oaks include white and chestnut oak; others include blackgum, aspen, and cucumbertree.
[d]Data from 20 stands on the Monongahela National Forest where operational applications of deferment cutting were applied.

many forest benefits. The species composition includes a wide variety of shade-intolerant and shade-tolerant species that is similar to that observed after clearcutting. Cultural practices, such as crop-tree release, can be applied once the canopy of the new age class closes to favor the growth and development of the most desirable stems such as northern red oak.

Residual basal area in the early, experimental deferment cuts averaged 20 ft²/acre. In early operational two-age cuts on the MNF, the target residual basal area ranged from 20 to 40 ft²/acre, with actual residual basal area averaging 39 ft²/acre. More recently, new prescriptions call for 20 to 30 ft²/acre. Although residual trees in the experimental cuts were all potential high-quality sawtimber, residual trees in the operational cuts also included trees to help meet wildlife habitat objectives. In practice, residual trees may be selected by many criteria to help the forest manager achieve a wide range of objectives.

Where residual tree quality is a concern, trees in weaker crown positions or trees that show evidence of stress before treatment are most likely to lose quality. For most species, the strong codominants will not suffer grade reductions after deferment cutting. To reduce logging damage, operations should be conducted during the dormant season from November through January. To reduce windthrow, residual trees should not be selected above skid roads close to the cut bank where roots are disturbed.

To meet regeneration goals, residual basal area should range from 20 to 40 ft²/acre. However, if small sawtimber or poles are retained, maximum residual basal area will be reduced to allow for crown expansion as the overstory trees mature. It also is important to cut all stems 1.0 inch d.b.h. and larger other than the desired residual trees. Cutting these stems during logging eliminates low shade that interferes with regeneration and provides suitable growing conditions for the valuable shade-intolerant species.

Two-age regeneration harvests should be applied no more frequently than one-half the recommended economic sawtimber rotation for local conditions. In the central Appalachians, economic sawtimber rotations are 90, 80, and 70 years for northern red oak SI 60, 70, and 80, respectively. As a result, two-age harvests could be applied every 40 to 50 years to maintain a two-age stand structure, and some individual trees can be retained indefinitely to satisfy goals for longer rotations. A concern with relatively frequent harvests is that many large poles and small sawtimber need to be cut at short intervals in order to provide adequate light for regeneration of a new age class. At age 40, even-aged stands in the region contain 75 to 100 codominant stems per acre, with an average d.b.h. of only 10 inches. To maintain a two-age stand structure, 20 to 30 of the best codominant trees need to be retained to reach maturity, while the remaining trees will be cut. A disadvantage of short cutting intervals is that many cut trees will be removed at a time when their potential growth and value increase are at a maximum.

Due to differences in the timing and frequency of harvest cuts, economic returns from silvicultural alternatives are seldom directly comparable on the basis of returns from a single entry. However, estimates of harvesting costs and roundwood values indicate that implementing deferment cuts

versus conventional clearcuts can reduce net cash flows from the initial regeneration cuts by $459 to $1,171/acre, or 18 to 26 percent, depending on site quality and roundwood price levels (Miller and Baumgras 1994; Baumgras and others 1995). These revenue reductions were estimated for fully stocked stands at age 80 years, and reflect the assumption that the residual trees were low-risk, dominants and codominants. These residual trees can make significant contributions to economic returns from future harvests, but diminish short-term returns to provide the desired non-timber amenities.

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Use of Molecular Genetic Markers in Forest Management

Craig S. Echt[1]

Abstract.—When managing forests for biodiversity or sustainability, attention must be given to how silvicultural practices affect genetic diversity. A new generation of DNA-based markers affords a greater detail of genetic analysis than previously possible. These new markers, SSRs or microsatellites, have been used to demonstrate genetic diversity and infer evolutionary history of red pine, something that has not been possible with other markers. SSR markers developed by the Forest Service Research Biotechnology Unit are also being used to monitor how methods of sustainable timber management affect genetic diversity and breeding patterns within white pine stands on the Menominee Indian reservation.

INTRODUCTION

Often the goal of silvicultural prescriptions is nothing less than the management, or manipulation, of ecosystems. The importance of considering the effects on the genetic diversity of forest species when making such management decisions has been expertly reviewed (Conkle 1992; DeWald and Mahalovich 1997; El-Kassaby 1992; Ledig 1988; Li et al. 1992; Millar and Westfall 1992; Namkoong 1991; Savolainen and Kärkkäinen 1992; Yang and Yeh 1992). Maintenance of genetic diversity is also part of the biodiversity standards that have recently been proposed for forest plantations (Spellerberg and Sawyer 1996). The most efficient way to monitor natural or managed changes in genetic diversity is with protein or DNA-based (molecular) markers that are neutral with respect to natural selection. (Definitions of various terms, such as 'genetic marker', are provided in the final section of this paper.) A recently discovered class of DNA-based markers promises efficient and thorough assessment of alterations in genetic diversity for select forest species. In this presentation, progress in the application of these markers to address issues in forest management will be described, as will the approaches being used to communicate the role of forest research to those involved or interested in resource management.

SSR MARKERS IN FOREST GENETICS

Microsatellites, or simple sequence DNA repeats (SSRs), came to prominence in the field of genetics only during this past decade, due in large part to their medical applications in human disease research and DNA fingerprinting. But SSRs are highly abundant and variable in most organisms, not just humans, and thus serve as a universal source of highly informative genetic markers. In pine genomes, for example, there are several hundred thousand SSR sites (Echt and May-Marquardt 1997). It is expensive and time-consuming to develop the molecular genetic information needed to use SSRs as genetic markers, but several forest research laboratories are involved in the process for pines (Echt et al. 1996; Fisher et al. 1996; Kostia et al. 1995; Smith and Devey 1994), spruces (Pfeiffer et al. 1997; VandeVen and McNicole 1996), and oaks (Dow et al. 1995). Preliminary results from research in the author's laboratory indicate that SSR markers developed in one species, can be used in closely related species, thus leveraging marker development investments. The major advantages of using SSR markers over other types of markers, such as isozymes, RAPDs, or RFLPs, is that they generally have a large number of alleles at a locus, allele identification is unambiguous, heterozygosity is easily determined, they can be used among all members of a species, and they are quickly and efficiently analyzed from very small amounts of plant tissue. Given the increased resolution of genetic discrimination possible with SSR markers, they can be considered the "Hubble telescope" of genetics research.

In addition to their presence in the nuclear genome, SSRs are also found in the DNA of chloroplasts, and can serve as highly informative organellar markers. A number of chloroplast SSR (cpSSR) markers are available for use in conifers (Cato and Richardson 1996; Powell et al. 1995; Vendramin et al. 1996). Since in many species chloroplast DNA is uniparentally inherited (in conifers it is transmitted through pollen), cpSSR markers can provide information about evolutionary lines of decent among populations.

Fundamental information about the SSR markers and their uses can be found on-line through the Dendrome Forest Genetics World Wide Web server. This information is provided and updated by the author as a service to the forest research community. The URL address for white pine SSR markers is: http://s27w007.pswfs.gov/Data/echt_ssr_primers.html, that for hard pine SSR markers is: http://s27w007.pswfs.gov/Data/chloroplast.html, and information about cpSSR markers can be found at: http://s27w007.pswfs.gov/Data/ hardssr.html.

RED PINE POPULATION DIVERSITY AND EVOLUTIONARY HISTORY

Background

Genetic diversity of red pine, *Pinus resinosa* Ait., is extremely low, perhaps dangerously low, throughout its range. Red pine is an important timber species in the northcentral and northeastern United States, as well as in Canada. In Minnesota, Wisconsin and Michigan alone there are almost 1.8 million acres of red pine, valued at over $3 billion, and this area is only a fraction of the North American range of the species (Leatherberry et al. 1996; Miles et al. 1995; Spencer et al. 1988). Knowledge of the amount and distribution of genetic diversity of red pine is critical to management of this important natural resource.

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Table 1.—Locations of red pine populations

code	provenance	seedlot#	lat./long.	Elevation.(m)
A	Nova Scotia, Beaver Lake	7010280	44.14/65.20	140
B	Ontario, Eldridge Twnshp	7030250	47.00/79.30	310
D	Ontario, Sioux Lookout	6830060	50.04/91.57	370
E	Quebec, Norway Bay	7023040	45.32/76.26	80
F	Michigan, Delta Co.	5780350	46.00/87.00	NA
G	New Brunswick, Tracy	7010310	45.43/66.42	60
H	Ontario, Macdiarmid	7030260	49.18/88.05	370

The high level of homozygosity observed in red pine is thought to have resulted from one, or a series of, population bottlenecks. The most recent drastic decrease in population size (a population bottleneck) to have affected the species as a whole is thought to have occurred during the last Pleistocene glaciation 20,000 years ago, when red pine was restricted to refugial populations in the Appalachian highlands of present day West Virginia (Fowler and Morris 1977). The disjunct, dispersed populations found throughout the species' current range promote inbreeding which further increases homozygosity (Fowler and Lester 1970; Mosseler 1992).

Morphological and phenological uniformity are characteristic of the species (Fowler 1964; Fowler and Lester 1970). While some variation among provenances has been reported, it is much less than what is observed for other northern pines and the heritability of the variation has not been established (Fowler 1965; Wright et al. 1972; Ager et al. 1983). A narrow genetic base puts red pine at risk of extinction from exotic pests, disease epidemics, or rapid climate change, and can be further eroded by mismanagement. Thus there is a need to efficiently identify sources of genetic diversity so that divergent germplasm may be preserved, both in the forests and in seed orchards where it could be utilized in tree improvement programs.

Results

Since no other marker system had previously revealed genetic variation in red pine, cpSSR markers were used to survey 159 individuals among seven populations distributed across the natural range of the species (Table 1). As expected, the higher variability of cpSSRs allowed population differences to become evident. Measures of within population diversity (Table 2) indicated that a population in Tracy, New Brunswick harbored more chloroplast haplotype variability than any other population, and that no two populations were genetically identical. Examination of the genetic relationships among populations, and of the distribution of haplotype differences among individuals within populations, indicated that red pine, as a species, recovered rapidly from a population bottleneck. These results lend strong support to the previously formulated population bottleneck theory, but what was not so evident from previous observations, and what the cpSSR data clearly indicated, was that individual populations of red pine arose at different evolutionary times and possibly from different lines of decent.

Table 2.—Measures of cpSSR haplotype variation within populations

Population	n_e	f_a	H_e
A	1.430	0.833	0.314
B	2.153	0.667	0.559
D	2.998	0.545	0.698
E	2.924	0.429	0.691
F	1.754	0.750	0.449
G	8.397	0.217	0.920
H	1.497	0.810	0.348

n_e, Effective number of haplotypes in each population
f_a, Frequency of the most common haplotype
H_e, measure of unbiased genetic diversity

Red pine is thus not a genetically homogeneous specie, at least where the evolutionary origins of individual populations are concerned. More extensive cpSSR surveys should identify populations throughout the range of red pine that have the highest levels of diversity, and thus help set guidelines for genetic resource conservation programs of red pine. Genotyping of populations with nuclear SSR markers will be needed to assess the degree of population genetic differentiation of genes in the nuclear genome. Since the chloroplast microsatellite approach revealed population genetic differences in a species characterized by no detectable allozyme variation, it should also be considered for studying population structures of other forest species that have low genetic diversity, such as Torrey pine, *Pinus torreyana* Parry ex Carr, (Ledig and Conkle 1982) or western red cedar, *Thuja plicata* Donn ex E. Don., (Copes 1981).

GENETIC DIVERSITY OF NATURAL AND MANAGED WHITE PINE STANDS

Background

To achieve sustainable and ecologically sound white pine management there is a need to know whether certain practices maintain native levels of genetic diversity, or whether they narrow that diversity and foster greater inbreeding within managed stands. When artificial reforestation is used, it is also of benefit to know whether there are genetic subdivisions, or subpopulations, of trees within a management area. Such knowledge is useful for establishing seed transfer guidelines.

A previous study of eastern white pine populations in Quebec found that there are high levels of isozyme diversity, high gene flow among populations and no measurable population genetic differentiation across the range (Beaulieu and Simon 1994). In an isozyme study of eastern white pine mating systems, essentially no excess of inbreeding was found in two natural Quebec populations that differed in their stand densities of from 800 to 100 trees/acre (Beaulieu and Simon 1995).

Table 3.—Populations samples from white pine stands and site characteristics

stand	overstory (density)	cone seeds collected	regen., natural	regen., artificial
SP	~240 yr (2/ac)	-	-	-
PP	~160 yr (40/ac)	-	-	-
MC	~160 yr (3/ac)	√	40 yr	-
C1	~160 yr (40/ac)	√	3 yr	-
OL	~160 yr (20/ac)	-	9 yr	-
EL	none	-	-	8 yr

Ongoing research in the Biotechnology Unit at Rhinelander involves assessing the genetic diversity of white pine, *Pinus strobus* L. A study is in progress with white pines managed by Menominee Tribal Enterprises in Menominee County, Wisconsin, to determine how certain silvicultural practices affect genetic diversity across the 234,000-acre reservation. Instead of isozymes, SSR markers developed by Echt et al.(1996) and cpSSR markers developed by Vendramin et al. (1996) are being used.

Here are some of the questions that the Menominee foresters hope to have answered by this research: Is gene diversity distributed equally among populations across the county? Does genetic variation and gene flow change under different management strategies? How does overstory density affect genetic diversity and degree of inbreeding among the regenerated progeny? Is off-site seed genetically equivalent to local seed sources?

Besides assisting forest managers in long-term planning of tribal resources, the Menominee study will supply additional basic information on white pine diversity in the North Central Lake States region. It is expected that regional white pine information eventually will be combined with data from eastern U.S. populations, and from similar studies occurring in Canada, to construct a continental database for white pine population genetic diversity and structure. Such information could be used in formulating area-wide management and planning decisions.

The Menominee Study Plan

Six sites, involving nine populations of individuals, were selected for study by Dan Pubanz, a Menominee Tribal Enterprises forester (Figure 1). Five of the site are actively managed, and the sixth (School Pines - SP) is representative of a remnant, natural population that has not been thinned. Of the five managed stands, one (East Line Plantation - EL) was artificially regenerated from off-reservation seedlings, three sites (Potato Patch - PP, Camp One - C1, Oconto Line - OL) are under shelterwood management, and one (Minnow Creek - MC) is a pine release management site. Age classes of the overstory and regenerated populations are provided in Table 3. Fifty individuals from both the overstory and regenerated generations at each site will be sampled. From the same 50 mature trees at the MC and C1 sites, which differ ten-fold in their overstory densities, seed will also be collected to estimate pollen flow and current levels of inbreeding and outcrossing that are occurring within the sparse overstory. GPS coordinates were obtained for all the trees sampled, so spatial genetic analyses will be possible to look for patterns in genetic differences within and among populations. Each tree, seedling, and seed will be genotyped for 10 nuclear SSR loci and haplotyped for 10 cpSSR loci. Statistical analyses will be performed to quantify genetic diversity and levels of inbreeding, both within and among individual populations. The nuclear marker data from trees and seedlings will provide information on how certain silvicultural practices affect levels of heterozygosity, inbreeding and gene diversity, while the nuclear SSR marker and cpSSR marker data from seeds and seedlings will provide information on patterns of pollen flow. Data from cpSSR haplotypes of trees will also be used to look at historic patterns of dispersal of white pine. Once the Menominee study is complete, the tribal foresters hope to use the genetic diversity information as part of the biodiversity component of their timber recertification process with Scientific Certification Systems.

Results

To date, DNA has been isolated from 450 trees and genotyping has been done for two SSR loci. Forty seeds will be collected from each of 100 trees in the fall of 1997. Although no firm conclusions can be drawn from just two loci, the preliminary results demonstrate the type of information that genetic surveying with SSR markers can provide silviculturalists.

The two SSR loci each had 14 alleles, which resulted in total gene diversity being high across the reservation ($H_t = 0.73$). There was very little genetic differentiation among stands ($G_{st} = 2\%$), meaning that diversity across the reservation was not highly structured. Even so, there were small, but significant genetic differences separating each stand such that genetic distance trees (phenograms) could be constructed to represent the genetic relationships of populations to each other. Naturally regenerated progenies, as expected, were genetically most similar to their parents, with the interesting exception of the Minnow Creek pine release management site. At that site the regenerated saplings had a distinctly different genetic makeup from the overstory trees that were left after thinning. The reason for this difference is not known and additional study is needed. Off-site seedlings (EL) were a bit less diverse than, but were genetically quite similar to, on-site seedlings.

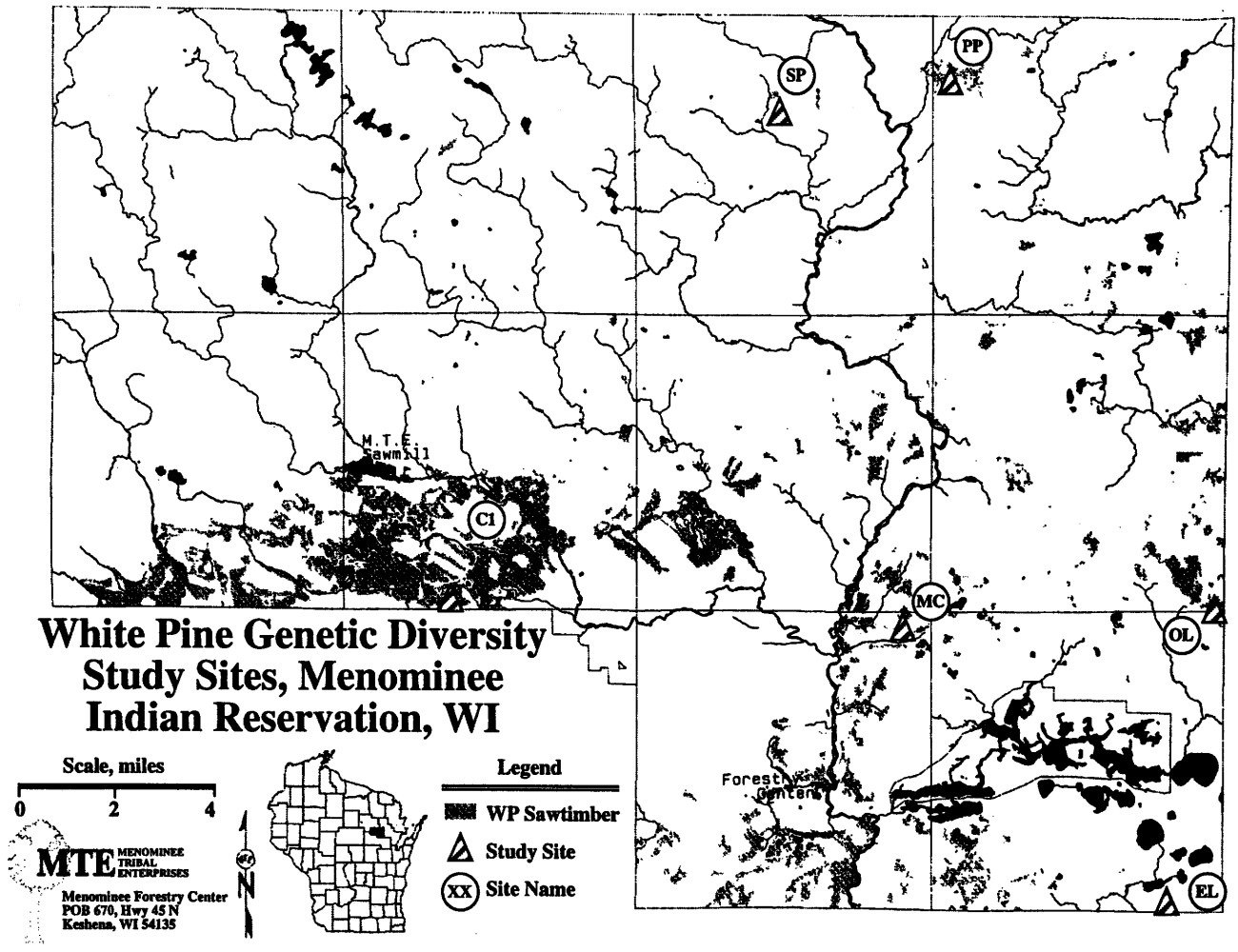

Figure 1.—Site map of study areas, and sawtimber white pine range, in Menominee County, Wisconsin.

Again based on data from just two loci, there was a general, but slight, deficiency of heterozygotes across the reservation (F_{it} = 0.20), suggesting that there has been more mating among relatives (inbreeding) than would have been expected in purely randomly mating populations. Inbreeding was always more pronounced among the parental generations. That is, there appeared to have been more inbreeding occuring 160 to 240 years ago than is occuring now in the managed stands. Since the regenerated seedling populations were less inbreed (more heterozygous) than their parents, Menominee silvicultural practices appear to be preserving, or even increasing, genetic diversity within managed white pine stands.

These preliminary results stand in contrast to a study of white pines in Ontario that used 18 isozyme loci, in which there were an average of only 2 alleles per locus, and gene diversity was about one sixth of that in the Menominee forests (Beaulieu and Simon 1994). While that study found a similar distribution of gene diversity within and among populations, the Ontario populations did not demonstrate an appreciable degree of inbreeding. Whether these differences result from differences between the information provided by isozyme and SSR markers, or from true biological differences between the populations, remains to be seen.

DEFINITIONS OF TERMS

Genome

The total genetic component of an organelle, individual or species. If only the word 'genome' is used, then it refers to all the DNA present in the nucleus. 'Chloroplast genome' and 'mitochondrial genome' refer to the total DNA present in those particular organelles.

Genotype, Haplotype and Phenotype

A genotype is an abstract, symbolic expression of the genetic factors (genes or loci) responsible for a phenotype. Genotyping is the process of determining the specific alleles that are present in an individual or population. While genotypes are expressions of the genetic constitution of diploids, where both sets of chromosomes are considered, haplotypes are expressions of the genetic constitution of haploids, where only one set of chromosomes (either the mother's or the father's) are considered. Scoring alleles in leaves or roots will give you genotypes, while scoring alleles in conifer megagametophyte or in chloroplast DNA, will give you haplotypes. A phenotype is an observable, heritable character, and is the physical aspect of the underlying

genetic factors. Once the genetic factors are identified, every phenotype can be symbolically represented by a genotype. A band on a gel, a cellular metabolite, or the angle of a branch, can all be considered phenotypes, as long as they are heritable characters.

Markers, Alleles and Loci

A marker is a quantifiable character that distinguishes, or marks, underlying genetic differences between individuals. It is often encountered as a particular enzyme or DNA fragment having a defined position on an electrophoretic gel. Any given 'band on a gel' does not gain marker status, however, unless two or more forms (alleles) of it exist at a single chromosomal location (locus). The plural of locus is loci. At their most fundamental level alleles are simply the DNA sequence variants found at a locus.

Oligonucleotide, Primer

DNA is a polymer of nucleotides, or a polynucleotide. A short piece of DNA is an oligonucleotide. An oligonucleotides usually refers to a piece of single stranded DNA, although it can be double-stranded, and is generally 10-100 nucleotides in length. An oligonucleotide primer, or simply, primer, is a single stranded oligonucleotide that anneals to a complementary sequence on single stranded DNA (the template DNA) and directs, or primes, the synthetic action of a class of enzymes called DNA polymerases. When two primers are used to direct the amplification of a locus by PCR they are called PCR primer pairs.

PCR (Polymerase Chain Reaction)

A Nobel Prize-winning technique for replicating and amplifying (cloning) specific DNA fragments in a test tube. The key component of PCR is a heat stable DNA polymerase called Taq polymerase, after the hot springs bacteria *Thermus aquaticus* from which it is purified. The extent of DNA that is amplified is determined by the two PCR primers which anneal to opposite DNA strands at the ends of the target DNA segment. In theory, millions of copies of target DNA can be amplified from a single DNA template molecule (a single cell!), but in common practice the starting point is several hundred copies of the DNA template. Thus, from just several hundred cells, a specific locus can be genotyped with a PCR-based marker. In pines, a typical PCR marker of 200 base pairs in length represents 1/100 millionth of the total length of DNA present in the nucleus. It is this discriminatory power of PCR that makes it the most powerful tool available for genetic analysis.

SSR (simple sequence repeat), or microsatellite DNA

A class of tandemly repeated DNA sequences that are highly variable, and which are used extensively as genetic markers. Examples of SSRs are $(AG)_{10}$ - the sequence of nucleotides deoxyAdenosine and deoxyGuanosine repeated 10 times - or $(ACT)_8$ - the sequence deoxyAdenosine, deoxyCytidine and deoxyThymidine repeated 8 times. SSR repeats are found in abundance throughout the nuclear DNA of most organisms. Each repeat that serves as a SSR marker is surrounded by unique, non-repetitive DNA. It is this unique DNA that allows identification of individual SSR loci along the chromosomes, while the embedded repeat DNA provides the informative variation. SSR loci can be analyzed by PCR once the DNA sequence of the repeat and its surrounding DNA is determined. These DNA sequences allow the unique PCR primer pairs to be designed and chemically synthesized.

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North American Long-Term Soil Productivity Research Program

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Abstract.—The National Long-term Soil Productivity research program was chartered to address National Forest Management Act concerns over possible losses in soil productivity on National Forest lands. The program supports validation of soil quality monitoring standards and process-level productivity research. Summarized results are supplied to Forests as collected. National Forest managers use them in developing forest plans and modifying management practices. Results are treated as the best available evidence and are used within the adaptive management process.

INTRODUCTION

Origins of the Long Term Soil Productivity (LTSP) program can be traced from informal discussions in 1986 between National Forest System (NFS) managers and Forest Service Research (FSR) scientists. NFS managers needed valid soil quality monitoring standards as a consequence of the National Forest Management Act of 1976 (NFMA), and sought help from Forest Service Research. Researchers needed a more fundamental understanding of site productivity and the processes controlling it to develop and evaluate alternative silvicultural systems. Open and active communication between researchers and managers led to a major review paper on the world' s experience concerning declines in fundamental productivity (Powers and others 1990) and a template for what was to become the LTSP program. Further technical discussion between Forest Service scientists, international scientists, and researchers from several U. S. universities and forest industry resulted in a generic study plan which was drafted and circulated for national review. In 1989, following national review, the LTSP plan became an official Forest Service cooperative program with the signing of the national study plan by the Deputy Chiefs for National Forest Systems and Research[2].

DESIGN AND IMPLEMENTATION

Background

Soil was selected as an indicator of site productivity potential because it is a fundamental resource that controls the quantity and quality of such renewable forest resources as timber, wildlife habitat, forage, and water yield, and because it is a non-renewable resource directly affected by forest management practices. The USDA Office of General Council interprets land productivity to mean the inherent capacity or potential of a soil to produce vegetation[2]. The LTSP program centers on two concepts:

1. the soil is the key site factor controlling productivity that is affected by management, and
2. the fundamental measure of productivity is the site's carrying capacity for plant growth.

Research has shown that productivity declines on non-wetland sites are related principally to site organic matter losses and soil porosity reductions (Powers and others 1990). Although concepts are well established, there is little specific understanding of how site organic matter and soil porosity are linked to control fundamental processes governing productivity or what threshold levels of organic matter and soil porosity are needed to maintain site productivity.

The national study has three main objectives:

1. Validating regional soil quality monitoring standards against soil productivity potential;
2. Determining the productive potential of the land for vegetative growth; and
3. Understanding how soil porosity and site organic matter interact to regulate long-term site productivity.

These objectives are best addressed by a designed experiment with treatments effecting large, systematic changes in fundamental soil properties. A controlled experiment is preferable to quantifying operational practices which are difficult to control, generally confound several variables, vary from region to region, and are likely to become obsolete.

Experimental Design and Treatments

Each installation of the study (Figure 1) consists of a core set of nine plots which represent all possible combinations of three levels of compaction (none, moderate, and severe) and three levels of organic matter removal (bole only, bole + crown, and total above-ground organic matter). The 1-acre plots are regenerated with the species or species group appropriate to each region. Each plot is split into two equal parts with one half receiving total competition control, focusing site resources only on the subject trees. The other half receives no competition control and the plant community is allowed to develop. Along with the core experiment, plots of ameliorative treatments and best

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[2]USDA Forest Service. 1989. Evaluating timber management impacts on long-term soil productivity: a Research and National Forest System cooperative study. Study Plan. 32 p.

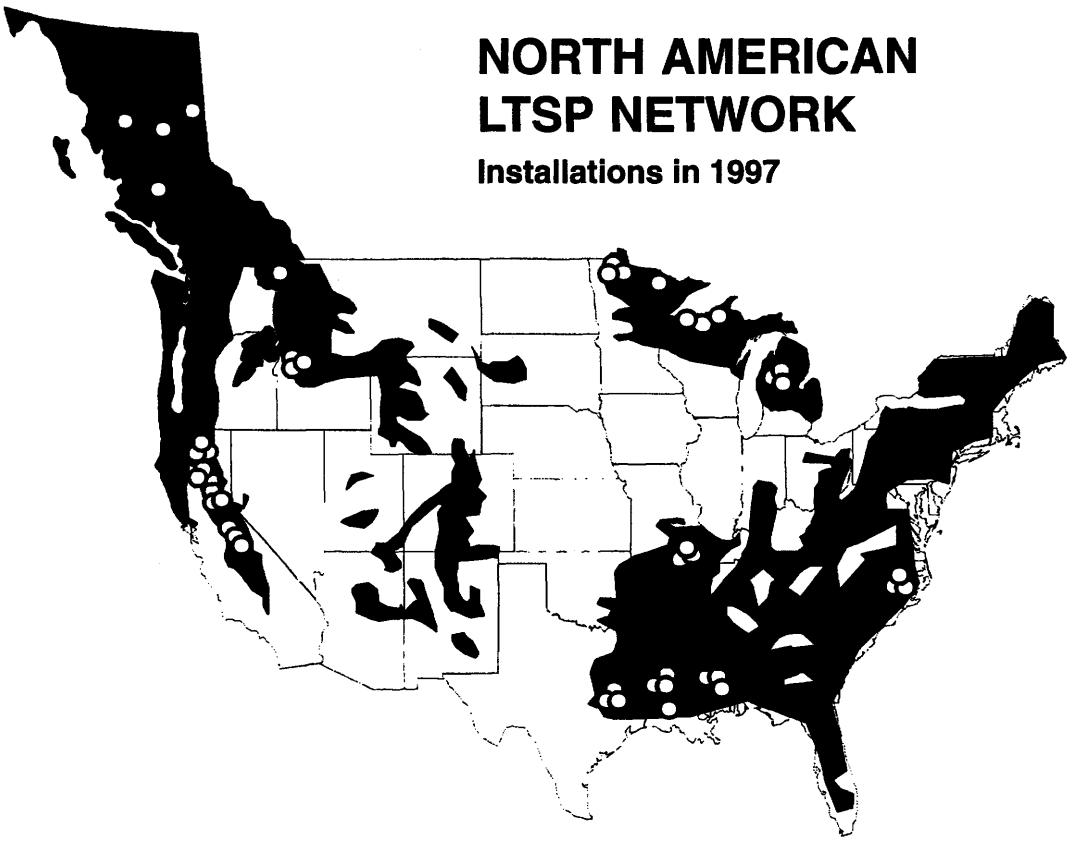

Figure 1.—Locations of current LTSP installations in North America.

management practices are added at many LTSP sites to see how soil productivity can be restored or improved. The standardized experimental design is shown in Figure 2. Most sites are on National Forests, but in Missouri the plots are located on state lands as is one installation in California. Researchers in the British Columbia Ministry of Forests, Canada, adopted the LTSP design and have installations at four locations with more planned. Locations of the current LTSP study installations are shown in Figure 1 and Table 1 summarizes the forests and species. Our discussion centers on the U.S. Forest Service phase of LTSP.

Candidate sites are arrayed along a gradient in soil properties believed to be directly linked to potential productivity, recognizing that the importance of any suite of properties varies by region. Study sites are selected from the candidates to cover the range of soil-site conditions found within a timber type.

Implementation

The design, installation, development of research of soil processes, maintenance and protection of this network was accomplished by direct communication between NFS managers

Table 1—Location and species of current LTSP study installations.

Region/ Station	National Forest/ Experimental Forest	Number of Installations	Species
1/RM	Priest River	1	Hemlock
4/RM	Boise	3	Mixed Conifer
5/PSW	Blodgett (Univ. CA)	1	Mixed Conifer
5/PSW	Eldorado	1	Mixed Conifer
5/PSW	Lassen/Black's Mountain	3	Mixed Conifer
5/PSW	Plumas	2	Mixed Conifer
5/PSW	Sierra	3	Mixed Conifer
5/PSW	Tahoe	2	Mixed Conifer
8/SRS	Davy Crocket	3	Loblolly Pine
8/SRS	DeSoto	3	Loblolly Pine
8/SRS	Croatan	3	Loblolly Pine
8/SRS	Kisatchie	1	Loblolly Pine
8/SRS	Kisatchie	3	Loblolly Pine
9/NC	Chippewa/Marcell	1	Aspen
9/NC	Chippewa	3	Aspen
9/NC	Huron	3	Aspen
9/NC	Ottawa	3	Aspen
9/NC	MO Dept. of Conservation	3	Oak-Hickory
BC[a]	Prince George	3	Lodgepole Pine/White Spruce
BC	Prince George	1	Aspen

[a] Plots in Prince George Province, Canada were installed following the specifications of the USDA Forest Service study and are considered part of the LTSP network for data analysis.

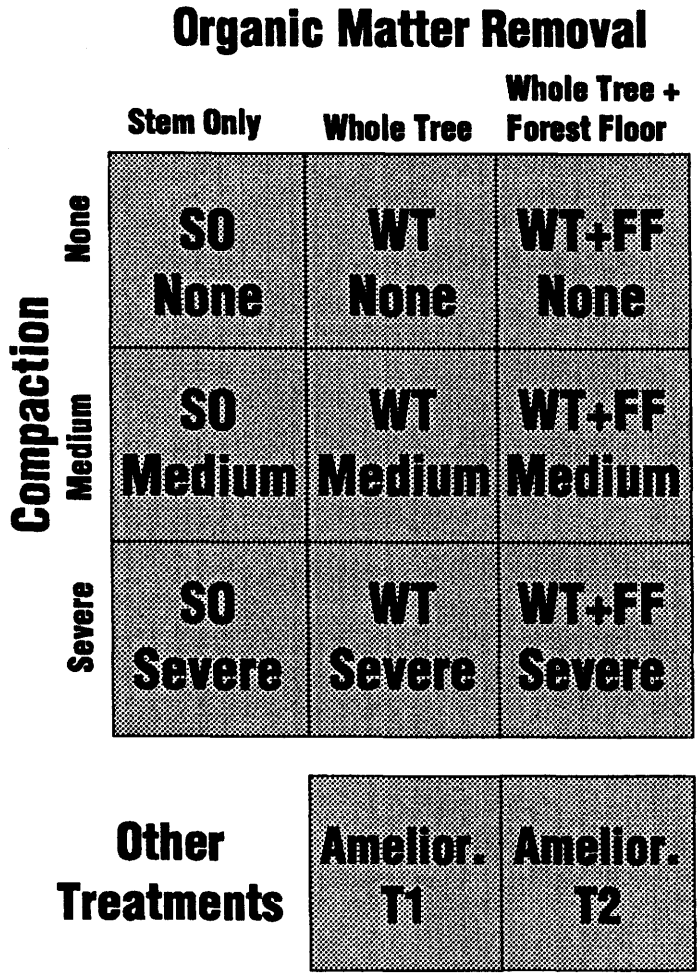

Figure 2.—Standardized experimental design for LTSP treatments. Each whole-plot treatment has competing vegetation controlled on one of the plot and the other half receives no competition control. Treatments to enhance productivity (amelioration) may be added.

and FSR scientists. Through times of tight budgets and shrinking resources, LTSP completed the demanding installation phase. The LTSP network exists because the right people in critical management positions were willing to take a substantial risk, key scientists agreed that the issues warranted a large research effort crossing Station boundaries, and through the willingness of Forest Service leadership to commit special funding.

An effort such as this can succeed only with continual commitment and regular feedback. In planning the study network, the founders included a communication plan within the generic study plan. This communication plan defines three committees and their roles in maintaining the LTSP effort.

National Oversight Committee. This committee is chaired by the Associate Deputy Chief for NFS. The National Oversight Committee consists of the appointed Chair of the National Technical Committee and at least one representative from each of the Washington Office staffs of Vegetation Management and Protection Research; Forest Management; Wildlife, Fish, Water and Air Research; and Watershed and Air Management. The primary duties of this group are to: 1) ensure that work is focused on the areas of highest national priority; 2) inform the Chief and Congress of progress and needs; 3) coordinate activities and seek and direct funding for the effort; 4) provide for a review of study proposals; and 5) review, evaluate and incorporate modifications to the proposals.

National Technical Committee. The National Technical Committee members are the Principal Investigators and Regional Soil Scientists involved in the study installation and maintenance and interpretation of study results. This includes members representing the British of Columbia Ministry of Forests and scientists managing other long-term productivity plots with designs and objectives similar to LTSP. This committee is chaired by a Forest Service Principal Investigator appointed by the National Oversight Committee. The primary responsibilities of this group are to: 1) assure that scientific methods are consistent and appropriate to meet program objectives; 2) provide for the establishment of a national database of research results; 3) communicate progress, needs, opportunities, and substantive findings to the Oversight Committee; and 4) coordinate and prepare results for publication. This group meets once per year near one of the field installations (Table 1.) to review progress.

Regional Steering Committee. The Regional Steering Committee (RSC) is composed of the Research Station Principal Investigator(s), Regional Soil Scientist and Regional Silviculturist. This group is charged with identifying study sites, developing collaboration with National Forests, Ranger Districts, and other researchers, preparing specific study plans, and implementation of studies. This committee shares the responsibility of ensuring public awareness of the program with National Forests and Ranger Districts.

For example, in Texas there was public concern about using clearcutting to harvest the timber required to implement the study. The Southern RSC worked with the National Forests & Grasslands in Texas and the public to develop the following alternatives: 1) No Action, as required by NEPA, 1969; 2) harvest 14 patch clearcuts 1.5-2.5 acres in size, with 30-foot borders around plots, and 100-foot borders thinned to a basal area of 30 square feet per acre outside the 30-foot borders; and the competition control portion of the study would not be installed; 3) clearcut approximately 90 acres to allow for the full study installation; and 4) clearcut approximately 40 contiguous acres to allow for half of the study to be installed (no competition control plots). The RSC made several presentations to interested groups about the study and the proposed alternatives. The presentations focused on management needs for the information; the value of the information that would be generated; and that the study was not a study of clearcutting, but used clearcutting as a means of creating needed conditions. Upon evaluation of the alternatives and

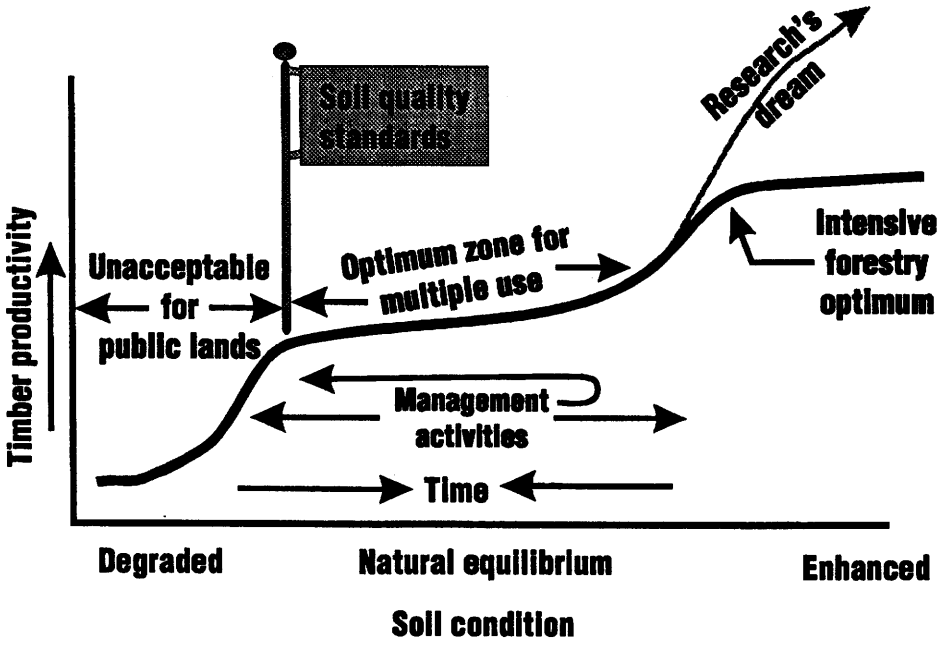

Figure 3.—Idealized relation ship of soil condition quality to productivity of a site. Soil quality standards are established to prevent degradation on the site which would lead to losses of productivity that have been define by law as unacceptable on public lands.

the knowledge value and tradeoffs associated with each, the decision was to adopt Alternative 3 and fully install the study because group selection (Alternative 2) affected management of twice the area and neither Alternatives 1 or 4 met the objectives of the study.

INTERPRETING AND USING RESULTS

Conceptual Framework

As in the inception and installation phases of the long-term soil productivity study, the communication of the results requires NFS managers and research scientists to remain focused on the common goal of validating soil quality monitoring on public lands. This is especially important for LTSP which crosses several administrative layers, is long-term and is producing volumes of useful results. Researchers, silviculturists, soil scientists, and administrators must understand how the results lead to interpretations related to policies and management of public land. The relationship between soil quality and vegetative productivity is the common focal point for LTSP.

In an idealized relationship between soil condition and timber productivity (Figure 3), soil condition is represented by a continuum broken into three zones of soil quality; natural equilibrium, degraded, and enhanced. Unmanaged forest soils reach a natural , dynamic state of equilibrium in physical, chemical, and biological characteristics. In a zone near this equilibrium, timber productivity is not maximized, but other organisms make significant contributions to the ecosystem. This is probably the zone that is optimum for multiple use as defined by Forest Service management policies. In this zone, low intensity management impacts shift the soil condition from the natural state. Without further inputs, the soil condition moves back to equilibrium. Thus, productivity changes associated with the changes in soil condition from normal management activities such as harvesting are small. With increased management intensity, timber production can be increased to a higher level, but possibly at the expense of other uses or resources. Usually this requires the application of several treatments such as tillage and fertilization simultaneously. These may be combined with other practices such as weed control and genetic selection that concentrate the productivity onto a target species. Unfortunately productivity also can be significantly reduced if the soil condition deteriorates beyond a threshold. If management activities degrade the soil below some threshold, productivity can collapse to a new lower level.

The concerns over productivity loss are expressed in legislation such in the National Forest Management Act (USDA Forest Service 1983) and Forest Service policies (U.S. Code of Federal Regulations 1985). These laws and regulations specify research and continuous monitoring to safeguard the land's productivity. As part of the effort to comply with this law, each Region has established soil quality standards meant to detect losses in productivity greater than 15 percent. Thus the soil quality standards, along with other policies, have established thresholds or red flags to prevent the soil from being degraded. These standards are designed to keep productivity from moving into the degraded zone.

Changes to Soil Quality and Productivity

Effects of Management. Preliminary results from the LTSP study illustrate our concepts. In Figure 4, the heights of the loblolly pines, *Pinus taeda* L., planted on the first LTSP site were compared with the heights of the harvested stand for the first 7 years. When low intensity harvesting was

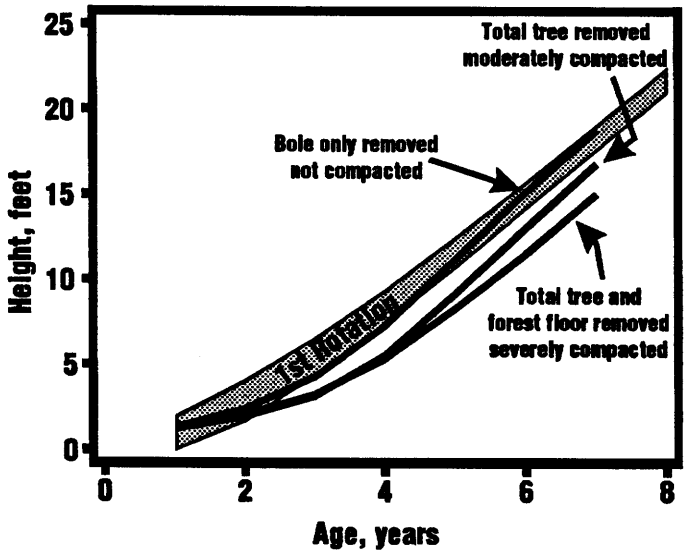

Figure 4.—Height growth over time of loblolly pine on plots treated with three levels of organic matter removal and soil compaction and the estimated height of the previous stand at the same ages. Plots are on the Kisatchie National Forest in central Louisiana.

employed, productivity was maintained at the same level as the original stand. At an intermediate level of harvesting impact, productivity was reduced, but the magnitude of the reduction appears to be getting smaller as the stand ages. Thus, with time, soil condition moves back to its equilibrium. The high impact harvesting treatment reduced height by about 20 percent compared to either the original stand or the low impact harvesting treatment and there does not appear to be recovery at this time. Thus, removal of all above ground biomass followed by severe compaction has degraded the site below acceptable productivity levels. On an operational basis, Region 8's soil quality standards should (and do) prevent harvesting impacts that are greater than the intermediate level. These results are confirmed by studies nearby which show even greater losses in pine productivity in the second rotation following disking or bedding during site preparation (Haywood and Tiarks 1995, Tiarks and Haywood 1996). Soil phosphorus is inherently low on both of these sites so the small amount of phosphorus removed in logging residues appears to have induced deficiencies. The loss in productivity and soil quality can be corrected with phosphorus fertilizer applications.

Losses in productivity are not limited to the timber species, and measurements of other stand components are included as well. On the Croatan National Forest, the number of species and biomass production was quantified by stem form class at 2 years (Table 2.) The number of species was significantly greater on the severely compacted plots where all above ground tree and forest floor biomass was removed compared to the plots not compacted and only the stems were removed at harvest. The greatest increase in number of species and in biomass occurred in the grasses and herb classes. However, the overall biomass on the highly impacted plots decreased by 43 percent compared to the low impact treatments. Increasing numbers of species in the grass and herbaceous classes may be a desirable outcome of management. However, because of the overall loss in productivity, compacting the soil or removing all of the logging residues is not an acceptable management tool and other alternatives should be used.

Results showing these declines are very effective in communicating the importance of soil quality standards to National Forest partners. Large and small private land owners also are concerned about such reductions in productivity as well as the increased productivity from amelioration of timber and other species in these systems. This led to the development of two important ongoing research partnerships with southern industries and universities which are closely linked to LTSP. The VPI/ Westvaco Sustainable Management Study was established with objectives similar to LTSP but with the additional

Table 2.—Number of species and biomass production in understory of stand at 2 years on Croatan National Forest without vegetation control after stem only removal and no compaction or total organic matter residue removal and severe compaction. (From Mellin 1995)

	Number of species		Biomass	
Stem form	Stem only not compacted	Total tree+ forest floor severely compacted	Stem only not compacted	Total tree+ forest floor severely compacted
	-------- number species/plot---------		----------lbs/acre----------	
Trees	18	12	974	409
Shrubs	20	20	2872	674
Grasses	7	16	147	1113
Herbs	8	15	12	71
Total	53	63	4005	2267

Table 3.— Ameliorative effect of bedding plus fertilizer with and without herbicide on loblolly pines at age 5 on the Croatan National Forest.

Treatment	height	d.b.h.	volume
	feet	inches	cu ft/ac
Stem only removal not compacted not herbicided	11.4	1.7	29
Stem only removal not compacted herbicided	17.3	3.7	193
Bedded and fertilized not herbicided	19.4	3.3	187
Bedded and fertilized herbicided	21.2	4.5	385

objective of determining if intensive forest management enhances productivity above natural levels (Powers and others 1996) in a sustainable way. Another study (Monitoring Productivity and Environmental Quality in Southern Pine Plantations) involving three forest industries, two universities and Forest Service Research was established to provide linkage between intensive plantation management and LTSP (Powers and others 1996). One of the first products of this LTSP-MPEQ linkage is a data base of biomass and nutrient contents of all the components of stands representative of the loblolly pine range and management intensities.

When possible, ameliorative treatments have been included as part of the LTSP installations. On the Croatan National Forest in North Carolina, herbicide, and bedding combined with fertilization both increased loblolly pine growth compared to the lowest impact treatment in the core LTSP design (Table 3). As the stands further develop, the long-term economic and biological impacts can be assessed. The dramatic differences in tree size and stand structure do demonstrate the impact management can have if rapid development of a stand is desired for species restoration, visual effects and even timber production.

Not all management practices or amelioration treatments have the beneficial effect that is desired and expected when applied. While the intent is to improve soil quality, in practice the operation can reduce soil quality and productivity shown as U-shaped arrow on Figure 3. Stump pulling was included as an ameliorative treatment in some of the LTSP plots in Idaho, but the negative effects on Douglas-fir, *Pseudotsuga menziesii* (Mirb.) Franco, seedlings was greater than the severe compaction treatment (Table 4). Many ameliorative treatments have the potential to impact soil properties in ways that are not initially apparent. Through monitoring, the real effects on these activities can be understood and the practices abandoned when results are not consistently positive. Subsequent research studies can be used to investigate soil processes involved and develop desired alternatives.

Effects of time. Time will push the productivity back to equilibrium for both the positive and negative effects of management, assuming the activity has not caused a permanent change to the site, such as slope failure. The amount of time for full recovery depends on the degree of degradation, soil and site properties, presence of weatherable minerals in the soil, clay type, and tree species. For example, compacted soils will eventually return to their natural state, but the length of time required depends on the depth of compaction, presence and depth of freezing and thawing cycles, and presence of expanding clays. In Mississippi, the upper 5 cm of soil in skid trails would be expected to return to the uncompacted level after about 12 years (Dickerson 1976). However, in Minnesota, where recovery should be faster that in Mississippi because of more freezing and thawing and higher levels of organic matter, soils showed little signs of recovery after 9 years at depths greater than 20 cm. Thus, the depth of compaction is much more important than soil properties, and recovery will be much slower in soils compacted deeper than 30 cm. The relative increase in bulk densities at planting and after a recovery period (Table 4) show some recovery in Minnesota and Louisiana but none on the compacted plots in Idaho. On the Louisiana site, the dominant understory was grasses which should speed recovery compared to the herbicided treatments. The lack of recovery after compaction in the Idaho soils, especially compared to the effects of stump pulling is unexpected. Compaction, as

Table 4.—Relative increase in bulk density at 0-10 cm and tree heights compared to uncompacted plots at three locations

Location	Treatment	Relative bulk density		Relative
		At planting	Post planting[a]	tree height[b]
		---------- percent of uncompacted----------		
ID	Severely compacted	23	26	-1
ID	Stumps pulled	25	-9	-18
MN	Severely compacted	19	15	-20
LA	Severely compacted not herbicided	9	2	-12
LA	Severely compacted herbicided	9	6	-16

[a]Post planting measurements were made 3 years after planting in ID and 5 years after planting in MN and LA.
[b]Tree species are Douglas-fir in ID, aspen, *Populus tremuloides* Michx. and *P. grandidentata* Michx., in MN and loblolly pine in LA.

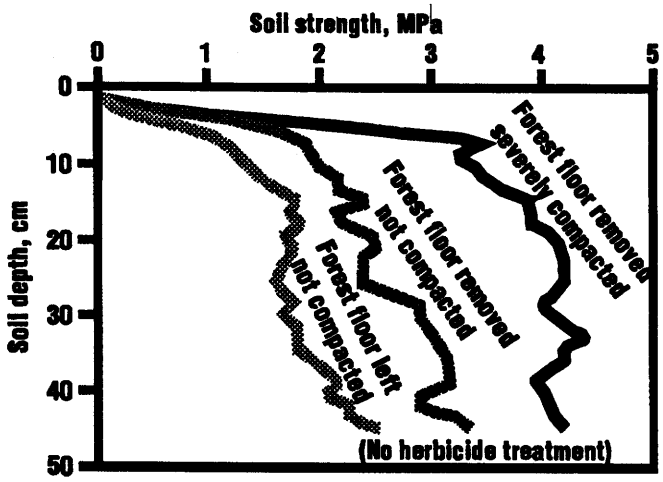

Figure 5.—Differences in soil strength with depth for three LTSP treatments at Challenge Experimental Forest measured in July.

measured by bulk density, also had mixed effects on the heights of Douglas-fir seedlings. These inconclusive results indicate that bulk density may not be the best indicator for monitoring soil properties changed by compaction.

Soil strength measured by a recording penetrometer is a faster way of assessing compaction and is sensitive to changes in bulk density and other soil properties such as water content that affect root growth. For many plants, root growth slows when soil strength exceeds 2 MPa and stops at strengths greater than 3 MPa (Whalley and others 1995). In California, soil strength was increased by removal of the forest floor sufficiently to reduce root growth even when the soil was not compacted (Figure 5). Removal of the forest floor allowed greater evaporation from the soil, raising soil strength as the soil dried. The effects of organic matter levels and soil compaction on other soil and biological process are being measured on various LTSP sites. At each location, ecosystem components related to soil quality at that site are being measured to increase the understanding of the processes involved. Examples of measurements being made at one or more sites include soil arthropod diversity, earthworm populations, types and numbers of ectomycorrhizal roots, soil organic matter quality, water regimes, and soil erosion.

Communicating Results. The committees that were established to plan and implement the study are being maintained and expanded to communicate not only the results of the study, but to aid in the adoption of management strategies. Each year the National Technical Committee meets at one of the LTSP sites along with representatives of one or more of the Regional Steering Committees, the National Oversight Committee, and investigators of studies that have been linked to LTSP. Status of the plots, growth measurements and successes and failures in monitoring efforts are shared and plans for more integrated measurements are finalized. This meeting is informal and facilitates open discussion of all aspects of LTSP.

In all Regions, LTSP results are communicated through the usual technology transfer process of workshops, conferences and publications. The RSC and the Forest Soil Scientist where the plots are located use preliminary findings in revising Forest Plans, to develop better monitoring methods and in ongoing operations. As an example, in the Kings River Ecological Management Area, monitoring forest soil impacts on growth in small openings proved to be very difficult. Instead, the findings on key soil variables from LTSP are used to develop methods of monitoring the soil to estimate effects on growth. In Mississippi, soil redox recording methods developed on the LTSP plots in Louisiana are being used to monitor the recovery of soil disturbed from salvage logging after a tornado. Easy access is being maintained to the sites so they can be used as demonstration areas to test soil quality standards and in the development of monitoring approaches for other resources.

To date, the LTSP study is a superb example on the national scale of the beneficial working relationship that exists at the local level. By networking, the local efforts have been leveraged, providing greater returns that the individual efforts would have. Now the challenge is in maintaining the study, both on the ground and in the Forest Service's thinking. Long-term experiments are like good wines in that they appreciate with age. As of this writing, the plots range in age from 0 to 7 years with the study designed to run 60 to 120 years. Thus, while the results may be tasted at these young ages, they must be treated as peeks at the more full-bodied rewards to come. It is imperative that any interpretations made using early results be treated as tentative and subject to change. Through these and similar efforts at all locations of the LTSP study, results are being applied to "Caring for the Land".

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Communicating the Story of Silviculture on the Allegheny National Forest

Lois M. DeMarco and Susan L. Stout[1]

Abstract.—To communicate the story of silviculture on the Allegheny National Forest, we need to distinguish silviculture—the art and science of manipulating forest vegetation to achieve management objectives—from forest management. During the field trip for the National Silviculture Workshop we visited five sites that demonstrate how inventory and monitoring, resource management, research, education, demonstration, and partnerships help communicate the role of silviculture. They also demonstrate communication to practitioners, policy makers, and members of the public who participate in setting management direction for national forests. On the Allegheny National Forest, our close association with our partners in Research and State and Private Forestry increases our effectiveness as communicators about the role of silviculture in managing this National Forest.

INTRODUCTION

For years, many of us thought of ourselves as both silviculturists and forest managers - as though these roles were one and the same. And for years, this was an accepted association. In recent years, it has become more and more apparent that these are truly separate roles. Management choices are made in concert with public participation. Silviculturists then identify and implement the silvicultural practices needed to achieve the desired management conditions. The joint silviculturist/manager role may have been effective in the past. Today, with increased public participation in our management decision-making process, there are some very good reasons to separate the roles of silviculturist and manager more distinctly.

Stepping away from center stage of the management debate strengthens our ability to show how silviculture can be used to achieve ecosystem objectives. It helps us show that silviculture is focused more on growing forests and helping vegetation develop to the desired condition than it is on making stumps. Silviculture is much more than maximizing volume or value production in an Allegheny hardwood stand. However if volume production is the selected management objective, we know a variety of techniques to employ to meet that goal. The management debate draws on the expertise of silviculturists and other specialists to assess management options. Management decisions then reflect a wide range of concerns.

Communication Themes

Silviculture is an integral component of the varied functions served by the Forest Service. We communicate the role of silviculture, both internally and externally, through policy making, inventory and monitoring, resource management, research, education, demonstration, and partnerships. We must effectively communicate what silviculture is, how it contributes to the management of the National Forests, and how we can use it to create the vegetative conditions that enhance ALL resources managed on the Forest.

Background

An understanding of the history and origin of the forests and vegetation found today on the Allegheny National Forest (ANF) is the foundation for today's silvicultural practices (Marquis 1975). The turn of the century timber industry made an indelible mark on the landscape - in terms of vegetation, structure of local communities and economies, and on people's perceptions of what kinds of wood products can be produced here. There are several other equally important developmental influences on this forest.

The oil and gas industry had its origin in nearby Titusville, PA where Francis Drake successfully drilled the first well in 1859. There was a period of exploration and development that peaked in 1883 and continued into the 1890's. Things remained relatively static until the 1920's when the development of new extraction techniques resulted in a resurgence of more intensive development (Ross 1996). Mineral development is a permanent feature on the Forest, as 93 percent of the mineral rights are owned by private interests.

The Forest provides a range of recreation opportunities, as well. By the 1920's, deer populations had recovered from near extirpation at the turn of the twentieth century sufficiently to begin attracting hunters from nearby urban areas and adjoining states. Fishing opportunities also attracted many visitors. The sporting traditions established several generations ago influence the expectations of today's hunters and anglers.

The Civilian Conservation Corps ran thirteen resident camps on or near the Forest during the 1930's. The men participated in a wide range of activities, many of which were geared toward restoring renewable forest resources or the development of recreation sites. Recreation sites developed by the CCCs increased popular use of the ANF for picnicking, swimming, and camping, and many CCC facilities are still in use today.

The national interest in the development of Forest Service recreation resources and facilities in the 1950's and 60's resulted in the construction of many developed campgrounds and recreation facilities along the Allegheny Reservoir shoreline. More diverse recreation development occurred in the last 10-15 years, including all terrain vehicle and motorbike trails, snowmobile trails, and the designation of the Hickory Creek and Allegheny Island Wildernesses

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and the Allegheny National Recreation Area. Recreation is big business; it provides more than twice as many jobs in the local economy as does the timber industry. Given that the Forest is located within a half day drive of one-third of the US population and half of the Canadian population, we expect that recreation demands will continue to increase over time.

The Forest Service established the Kane Experimental Forest in 1932, following the initiation of forest management research in 1927. This marked the beginning of what has become a very productive and supportive relationship between the Northeastern Forest Experiment Station Laboratory in Warren, PA (the Lab) and the ANF. Early studies focused on the growth and development of the young Allegheny hardwood stands, although researchers recognized problematic changes in herbaceous, seedling and shrub vegetation caused by the rapidly expanding deer populations of the 1930's and 40's.

A major silvicultural shift occurred in the east during the 1960's from uneven-aged to even-aged management philosophies. On the ANF and at the Lab, this shift focused attention on the establishment, survival and development of tree seedlings. In 1970, the Lab began an intensive effort to develop guidelines to ensure successful regeneration through silviculture. Today, managers on the ANF rely upon the research findings of the past 27 years as we implement prescriptions that support our management decisions.

There is intense interest in virtually every acre of this forest, usually by more than one user group, often with divergent points of view. Management debates are interesting - often intense and filled with emotion. As silviculturists, we can contribute information about the capabilities of the forest ecosystem to achieve different management objectives. Within these limits, we can suggest actions that will take us in the directions that our public wants us to pursue - all we need to know is the desired direction. To fulfill these dual roles for silviculturists—helping members of the public understand the capabilities of the forested ecosystem, and achieving management objectives—we must communicate effectively about the role of silviculture. The sites selected for the 1997 National Silviculture Workshop Field Tour represent our use of many different techniques to communicate the story of silviculture on the Allegheny National Forest.

FIVE SITES ON THE ALLEGHENY NATIONAL FOREST

We visited five sites as part of the field tour conducted during the National Silviculture Workshop (Warren, PA, May 19-22, 1997). Each exemplifies one or more strategies for communicating the role of silviculture in the management of the ANF. While the communication technique and silvicultural messages differ from site to site, there is one element common to all five. This is the strong partnership between the ANF and the Northeastern Forest Experiment Station Lab. Because of this partnership, researchers share information promptly with managers. Managers apply the information quickly and monitor its effectiveness in operational use. Monitoring information provides feedback for planning new research.

Hearts Content -- Communicating the Role of Silviculture through Demonstration and Education

One challenge we face in communicating the role of silviculture in National Forest management is developing a baseline understanding of ecological processes. A 120-acre remnant of the presettlement forest, Hearts Content Scenic Area has long been a favored site for forest visitors (Lutz 1930). Its importance as an ecological remnant is recognized by its designation as a National Natural Landmark. Managers from the ANF worked with scientists from the Lab and cooperators from the University of Indiana to select key messages and develop an interpretive plan. The interpretation includes multisensory (visual and tactile) signs and a self-guided tour tape. These help visitors understand ecological processes associated with the old-growth ecosystem, the history of the ANF, and the key role that deer play in this forest region.

Hearts Content vividly displays the interaction of natural factors that affect the development of an old growth forest. The impacts of years of over-browsing by white-tailed deer on understory vegetation (Whitney 1984), and the more recent, rapid impact of beech-bark disease on 200-300 year old beech trees are quite evident. The public can see and understand how browsing by white-tailed deer has prevented the establishment of any new age classes for the last 60 years. In the growing space vacated by deer browsing, resistant and resilient species like fern and beech have become dominant. Even as deer densities go down, these plants shade out seedlings of other species. Since 1985, the exotic beech scale-nectria complex has affected overstory beech in this area. Beech represented 40 percent of the trees in the original old-growth on the Allegheny plateau, but the beech bark disease complex is altering the structure and composition of the forest over time.

The messages are complex and raise several important questions for even the casual visitor. What does the future hold for our old-growth forests when key species are threatened with disease? What are the implications of this for overall forest health? If we can effectively explain the important ecological processes that are occurring on the "neutral ground" of an undamaged, old growth forest, then perhaps people will understand these challenges separately from the management decisions and silvicultural options available in managed forests. A well-thought out interpretive plan can communicate the role of silviculture in some surprising places.

Intensive Oak Reforestation Site - Communicating the Role of Silviculture through Resource Management

Our management activities themselves can be important tools for communicating the role of silviculture in National Forest management. In the ANF Land and Resource Management Plan (Forest Plan), approved in 1986, managers made a commitment to maintain the oak forest

type. When 18,000 acres of overstory oak mortality developed in 1988 in response to the first wave of gypsy moth defoliation and a severe drought, managers were forced to address two major issues. Should forest managers use pesticides during periods of insect outbreak and could forest managers overcome the historical difficulties associated with regenerating oak?

Public interest in maintaining the oak type resulted in a series of treatments in response to gypsy moth outbreak and subsequent tree mortality. The Forest treated 137,000 acres with an aerial application of dimilin and Bt from 1984 to 1993. Public reaction to this program was mixed, but pesticide use to maintain the oak seed source during insect outbreak has been accepted by most of the public. The high visibility of both gypsy moth defoliation and the resultant mortality helped build public acceptance.

Public support for maintaining the oak type continued, though mortality occurred. We explained the difficulties encountered in stand regeneration so that people would understand the intensive reforestation treatments we proposed. These included browsing by white-tailed deer, eliminating both acorns and seedlings, and understories dominated by species like fern, grass, beech and striped maple that prevented the establishment of oak species. The Forest carried out many reforestation treatments, including herbicide application, area fencing, tree planting, and individual seedling protection with tree tubes. Many of these treatments were in highly visible areas, along main roads and recreation and river corridors. We use these sites frequently for field tours to communicate with internal and external audiences.

Interpretive signing, readily accessible and observable sites that display the range of oak regeneration treatments, and field tours communicate our commitment to meeting the wishes of the public. A partnership with State and Private Forestry to inventory the scope of the oak mortality has been important, as are ongoing research and monitoring efforts by the NEFES labs in Morgantown and Parsons, WV.

Thinning Research - Communicating the Importance of Silviculture through Partnerships and to Policy Makers

Silvicultural research can create visually striking changes in forests. These differences can help policy makers and practitioners understand the role of silviculture in managing National Forests and other forests as well. This is especially true in the complex, stratified species mixtures that characterize the eastern hardwood forest. Species of widely different commercial, aesthetic, and wildlife values grow together at different rates. On the Kane Experimental Forest, researchers have installed and followed thirty-two two-acre research plots for this study. These show the separate and combined effects of residual stand density and residual stand structure on growth and development of even-aged cherry-maple forests since 1973 (Marquis and Ernst 1991; Nowak 1996). The contrasts created by these treatments have been invaluable during training sessions for practitioners, for loggers, and tours for policy makers. These contrasts demonstrate otherwise abstract ideas about the effect of intermediate treatments on stand value, structure, volume, habitat, and regeneration over time. These training sessions are sponsored by the Lab and Penn State Cooperative Extension, acting in partnership.

At the policy level, results from the research conducted on these sites forms the official basis for intermediate treatments on all public land and some large industrial holdings in Pennsylvania. The growth and yield model used for development of the ANF Forest Plan was developed using data from these plots, as was the widely used SILVAH decision support system (Marquis and Ernst 1992; Marquis and others 1992).

In 1992, the Lab/Penn State partnership organized the first logger training sessions in Pennsylvania using the Kane Experimental Forest research plots as key demonstration areas. These plots were so effective at communicating the role of silviculture that a new partnership was formed to install similar plots at seven other locations across the State. Penn State and the Lab worked with many other partners to find funding and to identify sites, install the treatments, design monitoring protocols, and interpret the new installations to users (Harmon and others 1997).

Allegheny Highlands Diversity Study - Communicating the Importance of Silviculture through Research

New research can also be an important tool to communicate the role of silviculture and the commitment of the Forest Service to expanded understanding of forest ecosystems. The silvicultural guidelines included in the Forest Plan are based largely on research completed on the Kane Experimental Forest, the ANF, State Forest lands, and nearby private industrial forest lands. The desired future condition described in the Forest Plan includes a more balanced age-class distribution and stands that continue to produce high-quality sawtimber. Realizing both these conditions requires successful regeneration of desired species after harvest. Effective herbicide treatments are essential tools for achieving regeneration success in the face of decades of deer browsing and the thousands of acres of fern, grass, beech and striped maple understories that interfere with the regeneration of other species.

The guidelines for herbicide-shelterwood treatments are based on nearly 20 years of research that focused on target plants and commercial tree species (Horsley 1992, 1994). In 1991, the Forest prepared an Environmental Impact Statement to amend the Forest Plan to include the use of sulfometuron methyl (in addition to glyphosate) in our herbicide program. The process involved an intensive public involvement effort that included field tours, correspondence, and several public meetings, some held as far away as Pittsburgh, PA. At the public meetings, we found that coordinated presentations were extremely effective for communicating our message. Resource managers presented the need for the reforestation treatment, while the scientist

who had conducted the experiments offered detailed explanations of the chemicals and their effects.

Through the public involvement process, we learned of the public's concerns regarding the impact of these herbicides on non-target organisms. The public gained an increased understanding and acceptance of the use of herbicides in our reforestation program. The Allegheny Highland Diversity Study is a direct outgrowth of the public meetings, promised in the final Environmental Impact Statement as a mitigation measure. This study will extend our knowledge by testing the impacts of operational herbicide-shelterwood treatments on songbirds, small mammals, reptiles, amphibians, and herbaceous plants at ten locations across the ANF (Ristau 1995, 1997). It is a formal research study conducted by the Lab.

Red Bridge Sugar Maple Mortality Monitoring - Communicating the Importance of Silviculture through Inventory and Monitoring, and Partnerships

Inventory and monitoring can communicate the importance of silviculture by providing evidence of the scale of problems that require silvicultural solutions. When ANF managers realized in 1994 that sugar maple decline affected nearly 90,000 acres of the 500,000-acre Forest, silvicultural intervention was an immediate consideration. Allegheny Forest Plan objectives include maintaining continuous forest cover and producing high quality sawtimber. Of the 90,000 acres of mortality, about 11,000 have >50 percent mortality/ decline, 30,000 have 20-49 percent, and 49,000 have 5-19 percent. Management options have been analyzed on about 76,000 acres. Based on a 1991 inventory conducted by the ANF, we know that on 70 percent of the ANF, plants that interfere with tree seedling development dominate the forest floor. This field trip site is a prime example, where even the seed source has been lost. The combination of overstory mortality and historic regeneration problems creates "forest decline." Reforestation is a key activity, but with such drastic forest change, managers are forced to work at the edge of their comfort zone with familiar silvicultural treatments. Adaptive management and monitoring become the norm.

Changing conditions, such as these, require ecological research to understand the reasons for change and research or adaptive management to develop or adapt silvicultural strategies to address changed conditions. The mortality is associated with many environmental stressors, and there is an aggressive multiagency interdisciplinary research program designed to assess the causes (Long and others in press) and develop appropriate long-term management responses. Stressors include three droughts within the last decade, defoliation of more than 70 percent of the ANF by one or more native and exotic pests, pollution stress (the Allegheny region receives some of the highest levels of nitrogen and sulfate deposition in the country), and nutrient poor, unglaciated soils. Sugar maple in the second growth forest is about twice as abundant as it was in the presettlement forest, and it appears on different landscape positions.

SUMMARY

Forest managers have relied upon the expertise of silviculturists and other specialists for treatment options in the day to day decision making of the management of our National Forests. One of our professional strengths is our ability to clearly define what impact silvicultural treatments can have on ecosystems, and how these actions can support the implementation of Forest Plans. Communicating the silvicultural message internally and externally can be challenging, but the rewards of doing so are great.

Communication can be strengthened by partnerships in our working environment. The Allegheny is fortunate to have a close working relationship with both the Northeastern Station and with State and Private Forestry in Morgantown, WV. The benefits of these partnerhsips show in the forest around us today and in the forest we are growing for the future.

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Bent Creek Demonstration Program

Erik C. Berg[1]

Abstract.—Bent Creek Research and Demonstration Forest scientists have transferred the results of research on the ecology and management of Southern Appalachian hardwoods since 1925. Since 1989, a full-time technology transfer specialist has led demonstration efforts. The demonstration program was designed to quickly transfer research results to interested users, and free-up scientists to conduct research. Tours of the experimental forest, a large photo point program, customized demonstration publications, short course offerings, and publications are the focal points of the Bent Creek program.

INTRODUCTION

Technology transfer is an essential task of any U.S. Forest Service Research work unit. Projects vary widely in their approach to the demonstration task. Most units prefer to assign technology transfer responsibilities to individual panelled scientists. Since the scientist is intimately familiar with his or her research, little is lost translating research findings to interested groups. A few research work units have filled technology transfer specialist positions; enabling scientists to spend more time conducting research.

Bent Creek Research and Demonstration Forest scientists found themselves spending vast amounts of time transferring research results in the late 1980's. Since the experimental forest is located less than a 30 minute drive from Southern Station Headquarters, visiting scientists frequently took time to tour the Bent Creek Experimental Forest. School groups, managers, and the general public were frequent guests.

The project leader decided to fill a full-time technology transfer specialist in 1989, to help meet the growing demonstration need. Bent Creek scientists have remained active in transferring information, but the day- to- day tasks are now performed by a specialist.

DEMONSTRATION PROGRAM COMPONENTS

There is nothing unique about the way information is passed along to users at Bent Creek. However, the research work unit enjoys an unusually strong emphasis on technology transfer. Specific activities include:

- tours
- demonstration cuttings
- photo points
- slide shows
- training
- custom literature searches
- personal contacts
- publications

Tours

About 800-1000 people per year tour Bent Creek as part of 30-40 groups. Target user groups include a wide array of students. Most of the forestry schools in the southeastern U.S. send both graduate and undergraduate students to Bent Creek annually. State forestry groups and industrial foresters use Bent Creek as an outdoor classroom for their personnel. Scientists and managers from eastern Europe and Asia have been visiting frequently since the late 1980's. Virtually all major research and forest management organizations in the southeastern United States have sent personnel to take the Bent Creek tour.

Visitors are drawn by the side-by-side array of demonstration forest cuttings. Since Southern Appalachian hardwoods respond quickly to disturbance, keeping the demonstrations fresh is a challenge. We are constantly planning for the next round of cuttings at Bent Creek.

Photo Points

We have installed photo points in all of the Bent Creek demonstration cuttings, taking fresh photos once every 3 years. We also maintain long-term photo points, dating back to the late 1800's. An example of this is the photo series of the Carl Schenk white pine orchard, located on the Biltmore estate. Photos taken in the 1880's clearly show severely eroded soils, typical of western North Carolina a century ago. Bent Creek scientists periodically took photographs of the 1899 eastern white pine plantation located on these eroded side hills. Photographs have chronicled the progress of this stand, the oldest white pine plantation in the southeastern United States.

Training

Bent Creek sponsors a wide variety of forest management and science training sessions, including two major offerings: environmental sciences training targeted at middle school teachers, and a hardwood silviculture shortcourse, designed for state and industrial foresters.

Teacher Training: Bent Creek personnel cooperate with Asheville-Buncombe Technical College and Western Carolina University staff to offer a two week long intensive shortcourse in environmental sciences. Our hope is that newly trained teachers will approach environmental education objectively, passing along sound science to their students.

Hardwood Silviculture Shortcourse: Every Bent Creek scientist, plus several outside speakers, focus their efforts on this annual training session. The shortcourse is designed to provide essential tools for silvicultural prescription development, including:

[1]Forester, Bent Creek Research and Demonstration Forest, Southern Research Station

- disturbance history
- site classification
- forest health
- economics
- wildlife
- stand dynamics
- hardwood autecology and synecology
- hardwood regeneration
- intermediate stand treatments

Future Training Efforts: We are planning to offer an advanced hardwood silviculture shortcourse. This new offering will be a hands-on, week-long series of exercises enabling participants to prepare sound prescriptions at both the stand and forest level.

Publications

The Bent Creek staff has created a variety of brochures, mostly targeted at the general public. A more recent endeavor is the development of focused literature reviews, which will provide the background information needed for topical brochures.

Evaluating and Communicating Options for Harvesting Young-growth Douglas-fir Forests

Dean S. DeBell, Jeffrey D. DeBell, Robert O. Curtis, and Nancy K. Allison[1]

Abstract.—A cooperative project, developed by Washington State Department of Natural Resources (DNR) and the Pacific Northwest Research Station (PNW), provides a framework for managers and scientists to (1) obtain experience with a range of silvicultural options; (2) develop information about public response to visual appearance, economic performance, and biological aspects associated with each option; and (3) demonstrate and communicate the consequences of applying the options (singly or mixes thereof) over the landscape to lay and technical audiences. The project is being installed as part of DNR's timber sale program on a 90,000-acre "working forest."

INTRODUCTION

Silviculturists at the Pacific Northwest Research Station's (PNW) Olympia Forestry Sciences Laboratory have joined with foresters of the Washington State Department of Natural Resources (DNR) to establish a comparison of options for harvesting and regenerating young-growth Douglas-fir forests. This project is an integrated research and development effort with elements of adaptive management and demonstration. It will provide a vehicle for communicating with policy makers and other parties interested in or concerned about silvicultural practices. It has been designed and laid out, and the first replicate block will be harvested in summer 1998. Many scientists from PNW laboratories, technical specialists from DNR, and faculty from the University of Washington and the University of Idaho are currently involved with the project and will participate in evaluation of the options. We expect others to join us in the future.

In this paper, we describe briefly the general setting of forestry in Washington State today and the concerns that stimulated DNR and PNW to work together on this project. We discuss some considerations that shaped our approach to the project design and describe the harvesting options to be compared. We then describe the general nature of evaluations, including use of computer-generated visual images of stand development. Finally, we summarize benefits expected from the project.

FORESTRY IN WASHINGTON STATE

Our project is concerned with forests west of the Cascades. This area, commonly referred to as the Douglas-fir region, contains some of the most productive forest land in the nation. Seventy-five percent of the land is capable of growing more than 120 ft^3 per acre per year (Note: only 13% of forest land in the nation and only 17% of land in the southeast has such high production potential). Of 9.5 million acres of timberland west of the Cascades, 56% is in State or industrial ownership, 21% is in non-industrial, private ownership; the remaining 23% are federal lands, primarily National Forests. Historically, forest products have dominated the region's economy, and they still are very important.

During the past 25 years, human populations have boomed, particularly in and around Puget Sound. Most people are urban and suburban residents; they appreciate the scenic beauty and other values provided in our forests. Many, probably most, of these residents are opposed to clearcutting. Wood supplies contributed by National Forests have diminished substantially during the past decade, but timber harvests and silvicultural issues associated with them are more important than ever—for harvests have accelerated on other lands.

Despite many well-publicized conflicts and legal battles over forest management, we believe that most forest users, managers, and owners are interested in the multiple benefits that forests of our region can provide. And these include wood products and the financial returns derived from timber harvests, which, in most instances, directly or indirectly finance the provision of other values.

CONCERNS OF DNR

DNR is one of the largest forestry organizations in the Pacific Northwest, managing more than 2 million acres of forest land in the State. Management objectives—as defined by law—are to generate income in perpetuity for trust beneficiaries. These beneficiaries consist of educational and other state and county institutions. DNR foresters must manage responsibly, and they must consider financial trade-offs and long-term productivity of the forest resources when they make decisions about harvest options and silvicultural practices. As a government agency, DNR must retain broad citizen support. Public concerns about visual effects of harvesting activities have become major considerations in DNR management decisions, especially along major travel routes. Such concerns have led to limited application of a wide variety of practices, particularly alternatives to conventional clearcutting, for which little management or research experience exists. Even when conflicts over visual appearance are avoided, DNR foresters question whether they are selecting the best approaches. Thus, they want to develop a tool kit of reasonable harvesting alternatives, with sound, quantitative information about public response to visual appearance, economic performance, and biological/ecological aspects associated with each alternative.

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CONCERNS OF PNW SILVICULTURISTS

Silviculturists at PNW Station have long recognized a need to develop and evaluate a range of harvest options (or silvicultural systems) to meet multiple objectives in managed forests. This long-term need has become more urgent because many organizations are now trying different approaches in attempts to satisfy various combinations of owner objectives, societal expectations, and regulatory requirements. In most instances, there is no opportunity to determine what is gained or lost in comparison with conventional clearcutting or even whether the desired objectives are attained. A few experimental projects exist but options tested are limited and, in most cases, do not permit evaluation of all major elements or considerations that are important in assessing trade-offs and making decisions. Although this topic is now a top Station priority, we lack the staffing and funding to carry out a large-scale, long-term effort alone, especially if done as a conventional research study. The need for harvest options and sound information about them is also important for National Forests, but constraints associated with the Northwest Forest Plan and fears of appeals currently limit effective participation of west-side National Forests as partners, especially for projects that require timber sales in the age classes and at the scale needed to evaluate options for managing multi-purpose forests.

OBJECTIVES AND PROJECT AREA

Given the above concerns, an excellent opportunity existed to design an operational-scale project to develop and compare options for harvest and regeneration on Capitol Forest, a State-owned forest managed by DNR. This forest is adjacent to PNW's Olympia Forestry Sciences Laboratory and contains 90,000 acres of highly productive land. Douglas-fir is the predominant species, but smaller amounts of western hemlock, western redcedar, and red alder are present. Most of the stands are 60 to 70 years old and would normally be considered ready for regeneration harvest. But DNR plans to defer regeneration of some stands until they are considerably older, and thus develop a more balanced age class distribution. The forest contains and abuts many scenic areas, is adjoined by many residences, and portions are visible from major travel routes. Much of the forest is surrounded by industrial lands where extensive recent cutting indirectly limits DNR options in many viewsheds. Thus, a specific objective of the project is to provide options that will ease conflicts between aesthetic values and timber harvesting.

STRATEGIES IN PLANNING AND IMPLEMENTING THE PROJECT

Early in the project, we agreed upon several principles that would guide its development. We believe these have contributed to its success to date and have strengthened relationships among participating individuals and organizations. These are:

Joint Design by Managers and Scientists.—Local managers and field foresters identified the driving issue—develop harvesting options that reconcile aesthetic values with economic return and sustained wood production in visually sensitive areas. Research scientists provided guidance in experimental design. Together, we developed (a) rational options (silvicultural systems), (b) ways to implement and test them, and (3) methods to obtain the quantitative data needed for useful comparisons.

Operational and Adaptive in Nature.—We believed that operational scale and feasibility were essential if the project was to provide useful information to managers and was to be effective as a demonstration area. We also agreed that our goal would be developing as well as comparing a range of silvicultural options. This means that some options will receive some silvicultural practices during a rotation that are essential for their success—even though the practices are unneeded and may not be applied in others. Weed control may be an example. The additional costs and complications will become a part of the evaluation.

Financial and Staffing Resources.—This project was not initiated in association with an increase in resources available to either organization, but we were committed to making it happen. It is part of DNR's timber sale program on the Forest; planting and other treatments will be done as components of on-going operational efforts. Similarly, evaluation procedures are planned so that those data which are absolutely essential can be collected within expected funding levels of our silviculture team and within the framework of DNR monitoring efforts. We hope to attract additional partners and funds, but these are not critical to the project's success.

Stand- and Landscape-level Considerations.—Because a major objective of the project was to obtain information for managing in visually sensitive areas, it was essential to design the project so that interpretations could be applied to forest landscapes as well as stands.

FEATURES TO FAVOR LONG-TERM CONTINUITY

Any project installed to compare silvicultural systems must continue beyond the careers of the initial participants. Over the years, we have formed opinions about factors that favor survival of long-term efforts, and have kept them in mind as the project developed:

Wide Range of Options.—Treatments were selected to cover a range that extends beyond that deemed optimum today. Social needs and desires change as do forest conditions. Even in multi-purpose forests, the relative importance of different values in the mix will no doubt differ 10 or 20 years hence.

Large Treatment Areas and Adequate Replication.—Size and the number of treatment areas must be sufficient to

accommodate the "environmental insults"—damage and mortality of various kinds—and still provide useful information. Larger areas are generally required for assessments pertaining to nontimber values such as wildlife habitat than for timber values alone.

Applicability to Major Portions of the Forest Land Base.—Project must be installed in an area representative of major portions of the land base—in this case, land that will be available for multi-purpose forestry.

Minimum Essential Expenses.—We wanted to minimize essential expenses so that the project can survive during the lows of financial cycles and when political interest declines. But we wanted to provide flexibility within the layout and basic data collection to accommodate additional work when resources permit.

Multiple Disciplines and Organizations.—Multiple disciplines and cooperating organizations increase cost-efficiency and permit more comprehensive evaluations. And such diversity in partners also will help buffer the project from the cycles of support that occur within and among disciplines and organizations.

Foster Support and Visibility Throughout the Organization.—Although this project was a grass-roots effort in the truest sense, efforts have been made and continue to be made to build support throughout the hierarchy of the two major cooperating agencies. These efforts have included visits to the site and discussion of the project with top administrators, and preparation of a formal project plan for approval and signature by DNR and PNW managers.

EXPERIMENTAL DESIGN AND OPTIONS

Given the foregoing considerations with overall strategy, including features to foster support and continuity, we decided to implement and evaluate six harvesting options (Figure 1). Each option will be imposed on areas of 35 to 80 acres in size, and will be replicated three times on Capitol Forest. We believe all options are biologically and operationally reasonable. We expect differences among them in public response as well as economic and crop productivity, but none would be ruled out at current stumpage prices. Four treatments are regeneration harvests; the other two extend the rotation age of the present stand (one with thinning; the other, without thinning; the latter "do-nothing" option could be a reasonable short-term solution in certain situations and it also serves as an "experimental" control for some kinds of assessments). The options will lead to even-aged, two-aged, and multi-aged stands, thus creating a wide range of stand conditions, habitat values, and visual appearances.

TECHNOLOGY FOR STAND AND LANDSCAPE VISUALIZATION

Because visual appearance of harvest cuts was a big consideration in the project, we needed an approach to evaluate public response that would be transferable to other situations. Reactions of people to harvesting are influenced by personal factors and by several on-site matters. Some of these on-site considerations include post-harvest appearance, changes over time (stand dynamics), and surrounding conditions, including the nature and extent of harvesting on the landscape.

Except for post-harvest appearance, it is difficult to provide designed comparisons of these considerations in real time and space. Recently, researchers at PNW's Seattle lab developed software to provide images of stands and landscapes from topographic and stand inventory data (McGaughey 1997). This visualization software has been linked with existing growth models (Oliver and McCarter 1996) to provide approximations of stand development over time.

The stand and landscape images shown in Figures 2, 3, and 4 demonstrate the capability of this technology. Topographic and inventory data from the first block (replicate) of our project, coupled with an existing growth model, were used to depict the initial stand conditions, the landscape after the initial harvest (all options) in 1998, and stand development over the next 60 years for the two-aged and group selection options. The software continues to be refined, both for general use and specific application to this project. We believe the technology—even in its present state—is valuable for demonstration and public interaction.

STAND AND LANDSCAPE EVALUATIONS

Tree Growth and Stand Development.—We have already established permanent sample plots to assess damage, survival, growth, and development of the residual stand components and regeneration. A substudy will compare performance of genetically selected stock vs. standard planting stock in some options.

Economics.—DNR foresters are keeping track of planning, sale preparation, and administration costs by harvesting options. Data on quantity and grade of products removed, production rates, and costs of harvest will be collected. This information in combination with other appropriate data and knowledge will be used in an overall economic assessment.

Visual Quality and Public Response.—Landscape architects and sociologists will use photographs, on-site visits, and computer-generated images to assess and understand public reaction to the various harvest options.

Other values.—We are currently examining the opportunities and costs for evaluation of wildlife habitat, fungi, and long-term soil productivity.

EXPECTED BENEFITS

Over the long term, the information and experience gained from the project will permit sound and defensible decisions about harvesting options, and should lead to improved multi-

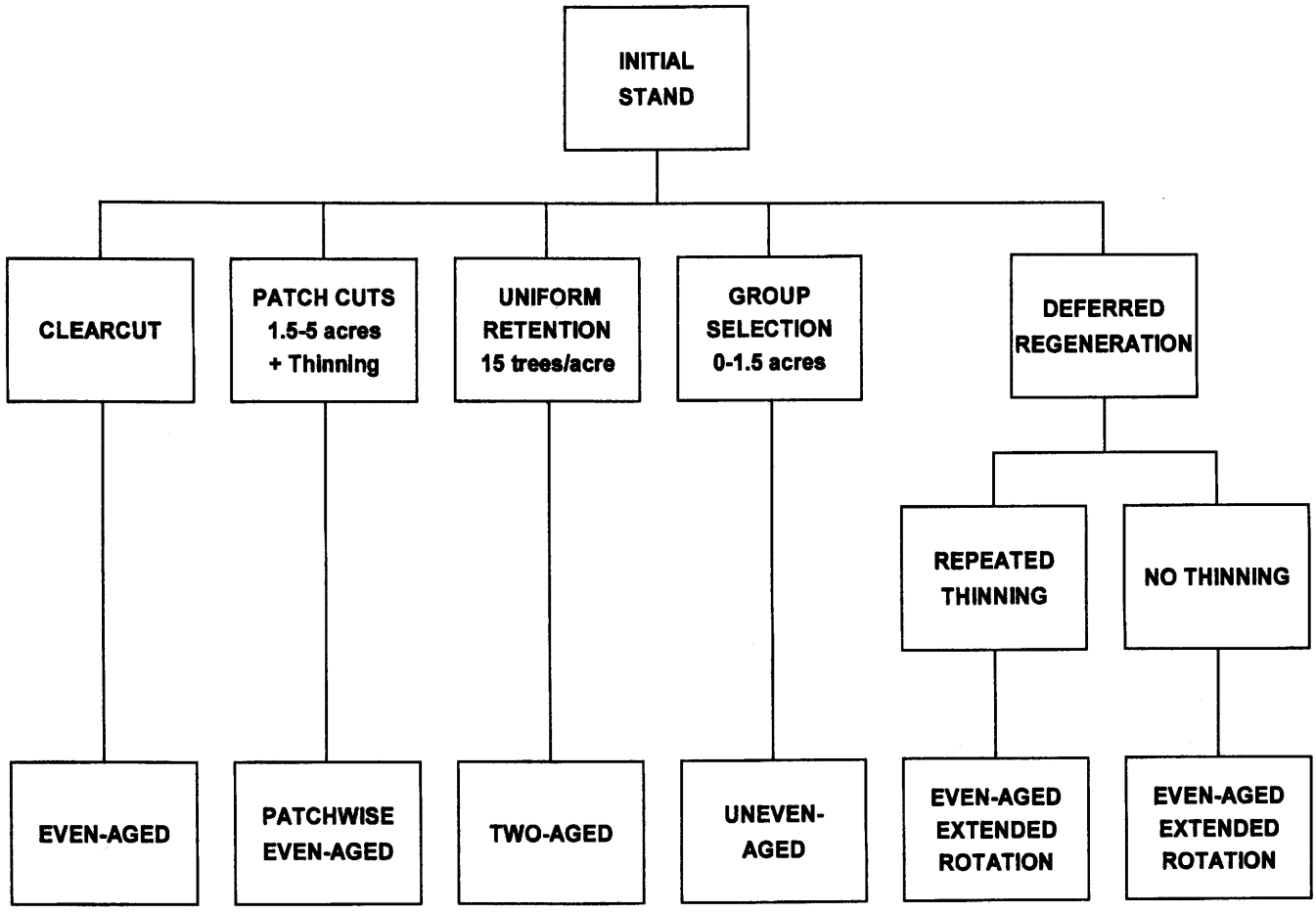
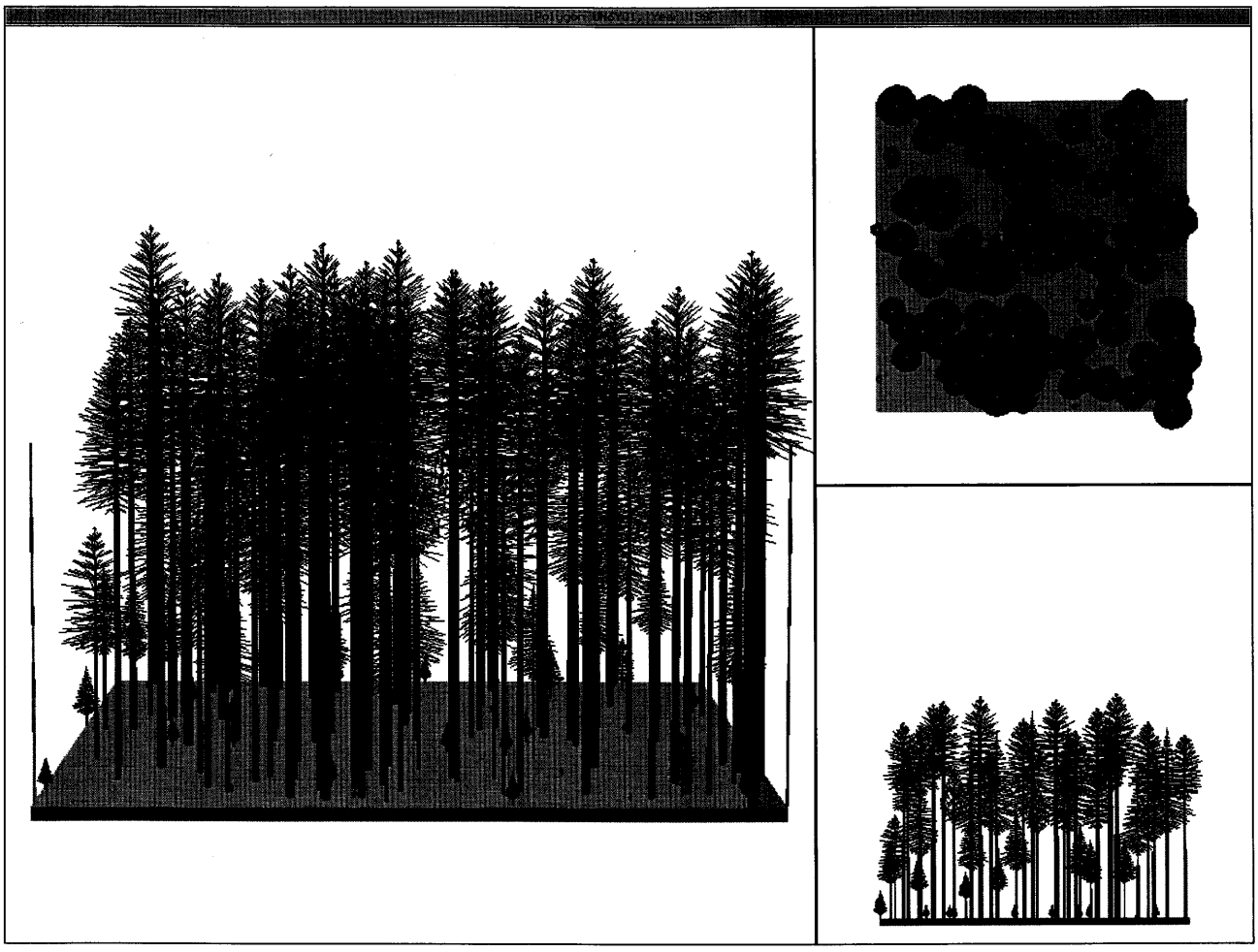
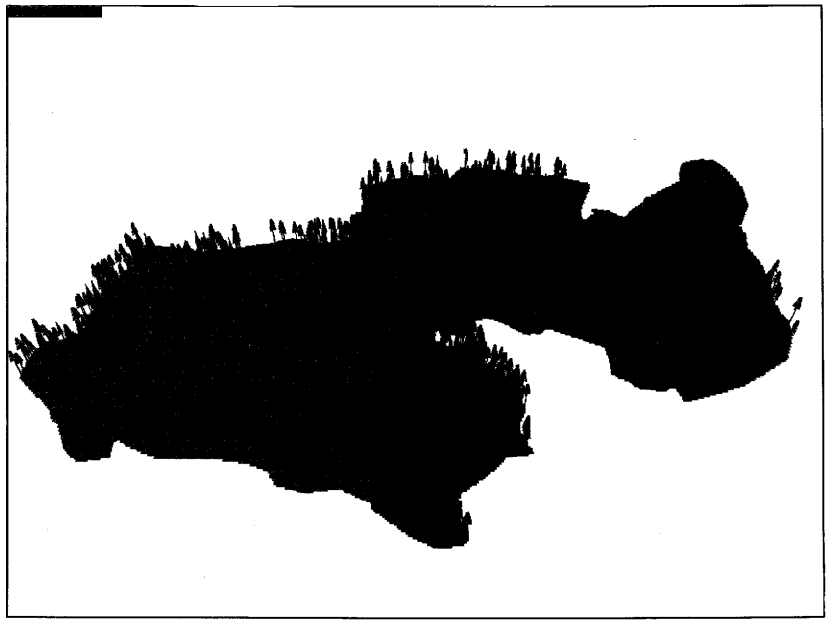


Figure 1.—Harvesting options compared in the projects.



(A)



(B)

Figure 2.—View of forest conditions in the first block of the project: initial within stand conditions (A), and landscape view of all options after initial 1998 harvest (B).

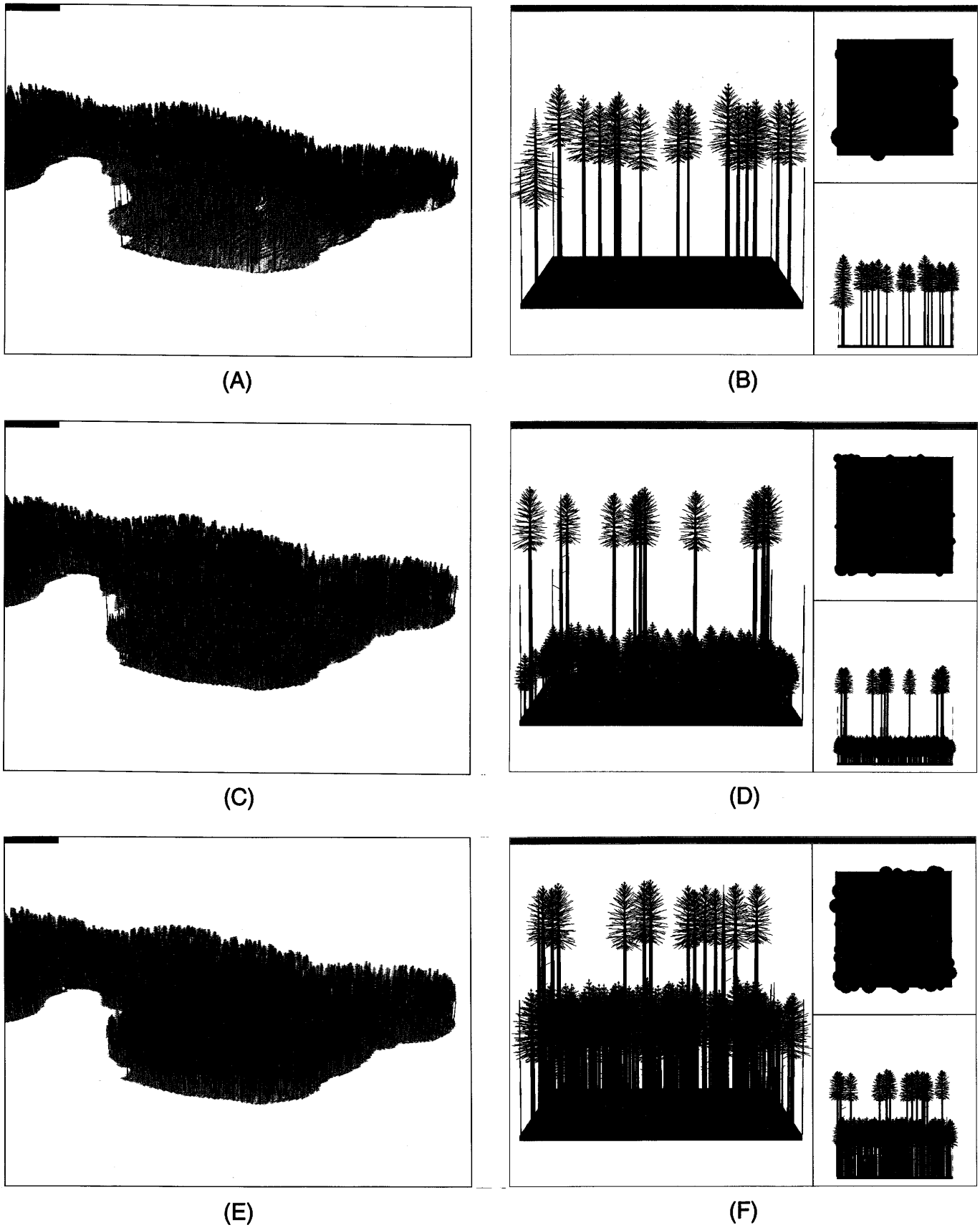
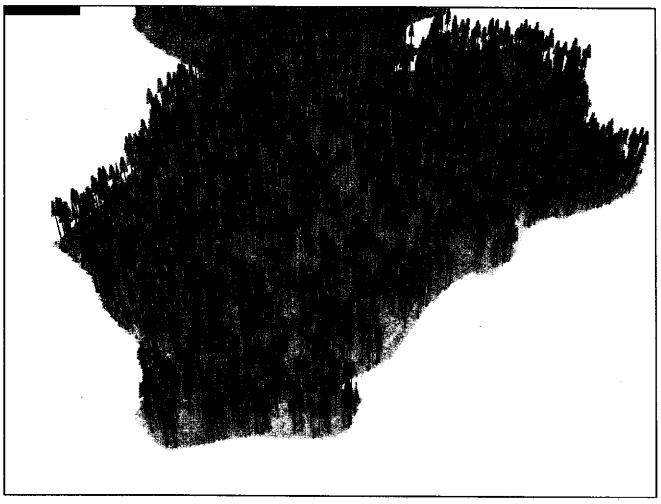
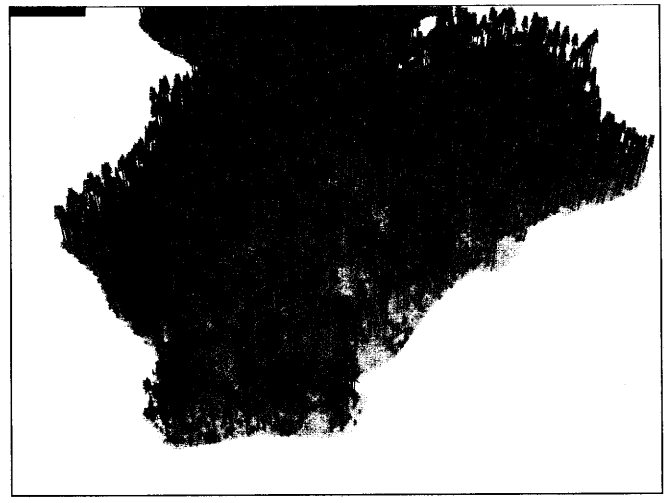


Figure 3.—Views of forest conditions over time for the two-age option: landscape and within stand views (A) and (B), respectively, after 1998 harvest; in 2028, (C) and (D); and in 2058 (E) and (F).



(A)



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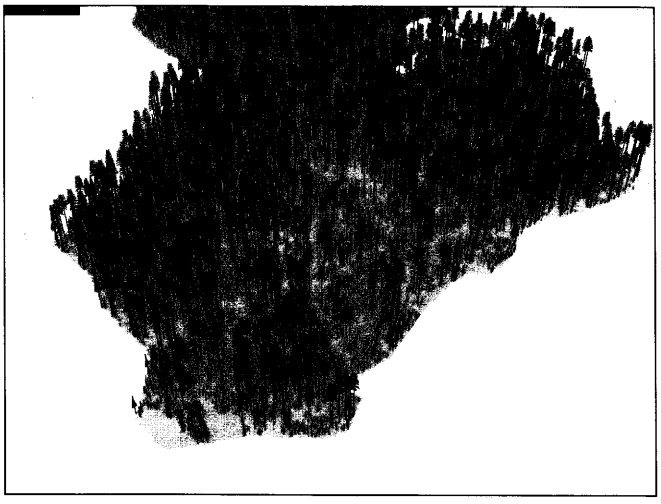
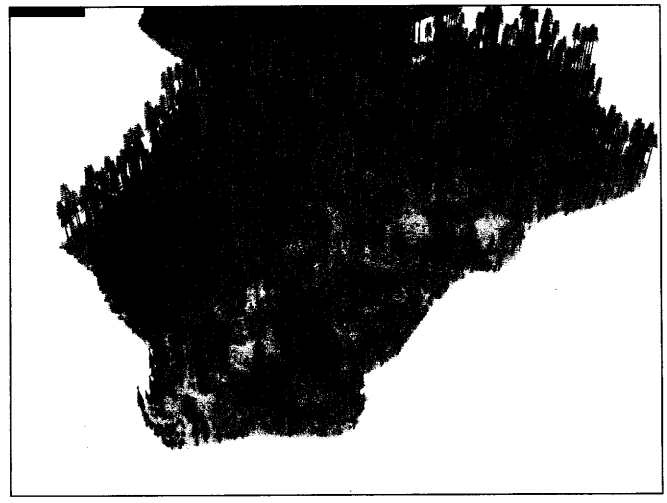
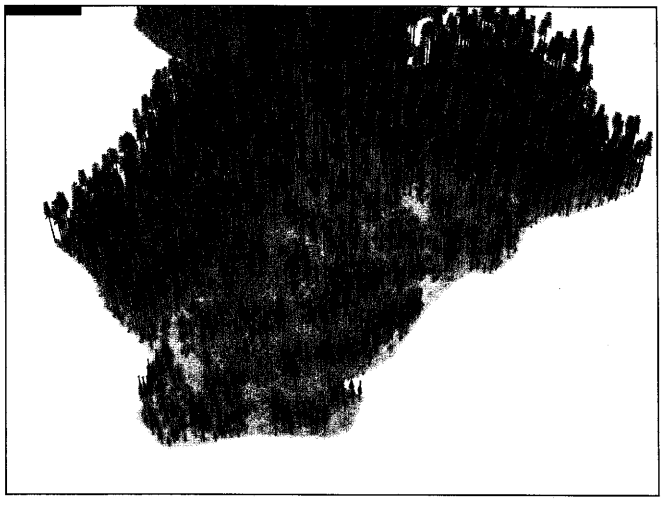


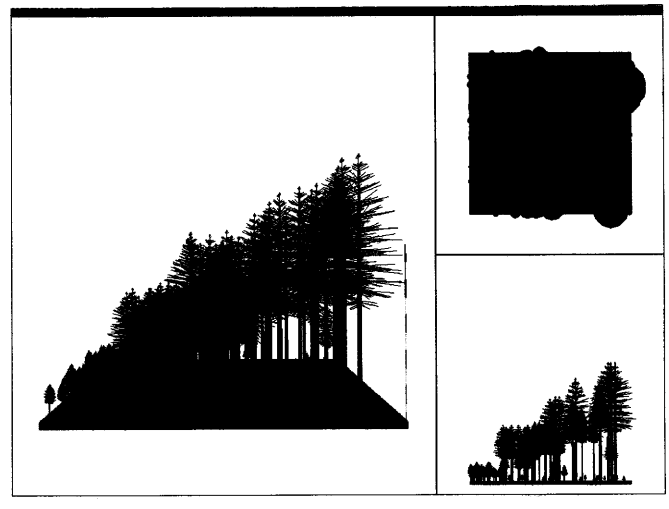
(C)



(D)



(E)



(F)

Figure 4.—Views of forest conditions over time for the group selection option: landscape view after harvest in 1998 (A), in 2013 (B), in 2028 (C), in 2043 (D), and in 2058 (E); within stand view illustrating size of reproduction expected in various groups in 2058 (F).

purpose forest management. There are also some near-term benefits:

- Managers and scientists have already obtained experience with adaptive management; that is, we have developed a design—to be implemented as a part of operations—that will provide useful information for modifying and developing harvesting practices.
- By next summer, we will have experience with planning, layout, and harvesting of timber sales, using the different practices. The problems and situations encountered will aid operational foresters and researchers in future work.
- The collaboration of sociologists, landscape architects, visualization modellers, and silviculturists will provide some information even before the area is cut. The visualization technology should be helpful not only in assessing public response, but also in fostering understanding about growth and development of stands and forests—their dynamic nature—and how silvicultural practice may affect them. And the real-life trials will provide a check on use of the simulated scenes, and will indicate changes needed to improve the visualization technology.
- Demonstration—This designed network of harvest units will provide a highly accessible showcase of the options and—with time—information on the costs and benefits associated with each and the trade-offs among them. We also hope to communicate and reinforce the idea that there is no one best approach or option to multi-purpose forest management. The initial emphasis of this project on visual characteristics should help to foster this broad outlook. It seems obvious that even for visual objectives alone, approaches must differ greatly in various situations. The availability of the visualization technology should also stimulate consideration of a wide range of options, and help us see how they can be mixed and matched on the forest landscape to provide the conditions and values desired in our forests.

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Seeing is Believing

Steve Wingate and David Wolf[1]

Abstract.—When people view forest management activities there is usually nobody present to explain or interpret what is actually taking place. They judge what has happened by what they can see. In the short term, many long-term, beneficial activities such as clearcuts or herbicide applications appear to the average person as destruction, and they often only view an activity at one point in time.

Photographing, typical management activities from the same location and with the same equipment over a period of years (photo point photography) demonstrates in a short period of time what has taken place over a long period of time. Growth of a new forest from seedlings to trees can be shown visually in a matter of minutes. Another benefit of photo point photography is the ability to record changes which can be studied at a later date.

People believe what they see. Their judgement of what they see is based on whatever information they have at hand at one moment in time. Rarely is there anyone on the scene who can explain or interpret silvicultural activities.

To the average forest visitor, a recent final harvest of cut stumps, horizontal tops, ruts, and muddy landings represent destruction. They cannot distinguish new tree seedlings from other ground vegetation. Whether viewed in person, on video or in a picture, a recent final harvest makes a negative, lasting impression which is frozen in time. Even when interpreted by a forester, the visual image is so powerful that it can defeat his or her credibility. Published in the media, this image can negatively effect the opinions of millions of citizens.

Changes in the forest environment usually occur over long periods of time and happen seemingly without notice.

Repeat or photo point photography is a way of credibly documenting change which has taken place over a longer period of time. This method of documenting change has been used by researchers and historians almost since photography was invented. A series of photos taken at Little Arnot Creek on the Allegheny National Forest beginning in 1927 shows the amazing transformation of an old-growth stand to a seedling stand, and its subsequent growth into the mature Allegheny Hardwood stand it is today.

Photo points can be used to follow the progress of any type of management or natural change. Later, the pictures can be displayed in minutes to explain what has actually taken place over a number years. The fact that the location can be identified in each picture lends credibility to the demonstration.

Subject matter on the Allegheny National Forest can vary widely and can include clearcuts, beaver ponds, oil and gas operations, fish structures, wildlife planting, road closures, landing rehabilitation, roadside activities, trail rehabilitation, scenic vistas, or dispersed camping spots. The most common subject matter is silvicultural activities such as shelterwoods, thinnings and selection cuts but also includes herbiciding, patch clearcutting, TSI, and many replications of other final harvest cuts. Other sequuences cover the long-term effects of different logging systems and rehabilitation techniques. There is also extensive coverage of a large tornado which occurred in 1985.

One of the most dramatic series shows a stand before and after clearcutting followed by the steady growth of seedling into a sapling stand. This series was used on the television show "Pennsylvania Outdoors" to illustrate how forests are regenerated. The producer blended each successive slide so that on video the stand seemed to actually grown in front of the viewers eyes.

On the Allegheny National Forest, the photopoint program is actually accomplished by a Dave Wolf, a volunteer. He keeps track of over 150 photo points. Each point is periodically reviewed and re-photographed at one, five or ten year intervals. Dave has kept the program going for over 14 years. He recieves help from Forest Service personnel in locating the subjects, modest compensation for his out of pocket expenses, and a place to store his materials.

To be credible, photo point photography must be properly done. It is important to use the same type of camera, lens, and film speed. The points should be photographed at about the same time of day, time of year and, in similar light conditions.

When the subject matter is chosen it is very important to pick the right place from which to take the photograph. The photographer should select a long-lasting object such as a rock or stump to use as a reference point in each picture. The lens and focal length should be planned to insure that what is being observed will always remain in the scene as trees grow, roads get wider and vegetation spreads. We have many slides of regeneration cuts that began as panoramic views of slash and distant tree lines, and that now appear as a wall of vegetation which fills the photograph.

To accomplish these things, a record of each photo point must be carefully maintained. Many of the points have a permanent reference stake installed in a safe location. The photo point form has an attached map to show the general and detailed location. The actual point is measured from the reference stake or object by distance and azimith. The scene and the reference object is recorded on the form as well as the dates and times of previous photos. Dave finds it helpful

[1]USDA Forest Service, Allegheny National Forest

to bring along the most recent slide when going to take a repeat picture. He then compares the slide with image in his view finder to fine-tune the current picture.

The slides are filed in indexed plastic slide holders. When slides are needed to explain a treatment to the public, the appropriate subject can be located from a master list. The slide holder is then retrieved and can be quickly viewed on a light table or displayed with a slide projector.

It is time consuming to do this work well, and the benefits are often intangible and long-term. It is the kind of work that usually suffers when budgets are cut. Volunteers can be an effective way to keep the program going in lean years.

Conclusion: Repeat photography can be an important and credible way to demonstrate the long-term effects of forest management to the public. A series of pictures can show that the unattractive image of timber harvesting is temporary and actually results in the rebirth or growth of the forest. It can also be used to show the results of many other types of management.

To be credible, photo point photography must be carefully done. The observer should be able to see that the image is of the same spot each time even though the size and the shape of the vegetation changes. When variation is minimized, these photos are readily adaptable to video presentations.

As we learn to communicate with changing technology, being able to display convincing positive visual images is essential. Photo points can offer a believable picture, video or digital display of change in the forest.

Reference: MacCleery, Doug. 08/23/85. Repeat photography for Assessing Ecosystem Change: A Partial Listing of References. USDA/Forest Service.

An Historical Overview of Forest Service Silvicultural Activities in Puerto Rico and the Caribbean Islands

Peter L. Weaver[1]

Abstract.—Forestry has a long history in the Caribbean Islands, in particular, in Puerto Rico. This experience, implemented in recent years through numerous partnerships, involves research, inventory and monitoring, and resource management, and has been communicated through demonstration and educational activities. Much of this history is documented in the 24 volumes of the Caribbean Forester, in 58 years of Annual Reports or Annual Letters written by the U.S. Forest Service's International Institute of Tropical Forestry (IITF), in forestry bibliographies, and numerous publications in scientific journals as well as the proceedings of seminars, meetings and conferences. Forest managers and researchers, not only in the United States, but also in the international arena, have been the recipients of information on tropical forestry through the IITF's library and its program in international cooperation. The purpose of this paper is to briefly summarize Forest Service activities in Puerto Rico and the Caribbean.

INTRODUCTION

Silvics and silviculture were defined many years ago (Baker 1950) but have become more complex with time. Silvics is the knowledge of forests and forest trees—how they grow, reproduce, and respond to changes in their environment. Biological information, however, has blossomed since that definition was proposed. Silviculture, in turn, was defined as the handling of the forest in view of its silvics—a practice modified by economic factors. Silviculture is also modified by environmental concerns and is formulated in different cultures in response to human needs and influenced through varying degrees of local, national and international involvement, and politics. Deforestation, biodiversity, neotropical migratory birds, biomass plantations, sustainable management, ecosystem management, urban forestry, timber certification, and global climate change have become major silvicultural topics at home and abroad.

Much of the IITF's program involves neotropical countries where the common languages are Spanish and Portuguese, and the culture, working environment, and way of doing business contrast with those at home. Moreover, forestry operations are characterized by selective harvest of prime species and poor extraction techniques. Limited budgets and inadequate staffing make control over forest lands, many distant from the central offices, virtually impossible. A complex forest planning process is absent or perfunctory and many key forest administrators are only casually familiar with forestry.

The purpose of this paper is to review IITF's involvement in communicating silvicultural information for managing neotropical forests including those of Puerto Rico and the U. S. Virgin Islands. Special emphasis is given to educational approaches although the other topics considered in this conference (eg., forest inventory and monitoring, research, resource management, demonstration, and partnerships) are an integral part of the IITF program. Without them, the educational aspect would be greatly diminished. This review, intended to be comprehensive but not exhaustive, touches on the more important activities and references only a fraction of IITF's publications. Throughout the text, the following acronyms are used:

CEER ... Center for Energy and Environmental Research (Univ. of Puerto Rico)
CITES ... Convention on International Trade in Endangered Species
CNF ... Caribbean National Forest (management designation)
DNER ... Commonwealth Department of Natural and Environmental Resources
FAO ... Food and Agricultural Organization of the United Nations
ITF (IITF) ... International Institute of Tropical Forestry (research)
ITTO ... International Timber Trade Organization
IUFRO ... International Union of Forestry Research Organizations
LEF ... Luquillo Experiment Forest (research designation)
LTER ... Long Term Ecological Research (National Science Foundation)
MAB ... Man and the Biosphere Program (UNESCO)
UNESCO ... United Nations Educational and Scientific Organization
USAID ... United States Agency for International Development
YCC ... Youth Conservation Corps
YACC ... Young Adult Conservation Corps

HISTORICAL PERSPECTIVE OF FORESTRY ACTIVITIES

The history of forestry in Puerto Rico and the U. S. Virgin Islands is briefly summarized in four documents that outline institutional programs, research and publications (Brown et al. 1983; Mosquera and Feheley 1984; Wadsworth 1970, 1995). Highlights extracted from these documents follow.

In 1876, the Spanish government proclaimed forest reserves in Puerto Rico including nearly 5,000 ha of the Luquillo Forest in the northeastern part of the island (later additions increased the land area to 11,300 ha). In 1898, after the Spanish-American War, ownership of crown lands in Puerto Rico were transferred to the United States. In 1903, the United States proclaimed the Luquillo Forest as a reserve and in 1907, as a national forest. Boundary surveys were conducted in 1916, mahogany was first planted in 1931, and the first forest inventory was completed in 1937.

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An Act of Congress (McSweeney-McNary Forest Research Act of 1928) designated a nation-wide system of forest experiment stations which included one in the West Indies. In 1939, the Tropical Forest Experiment Station was designated and funded in Río Piedras, Puerto Rico (in 1961, it became the ITF, and in 1992, the IITF). In 1940, the CNF staff was transferred to the station where it published the first of its annual reports and the first of its 24 volumes of the Caribbean Forester. Subsequent research concentrated on the tropical forest environment, regeneration, silviculture of secondary forests and plantations, mensuration, management, and the economic value of forests. Species trials began throughout the island and today more than 100 native species and 350 introduced species have been tested. Long-term monitoring of permanent plots began in 1943 and the first timber management plan was completed in 1949, the same year that the Baño de Oro research natural area was set aside in the LEF.

In 1953, the ITF began the first of its international tropical forestry short courses. In 1956, the CNF was also administratively designated as the LEF to recognize the importance of research. From 1956 through 1970, about 2,800 hectares of lower montane forest were thinned. In 1959, Caribbean Pine was successfully introduced in Puerto Rico and in the early 1960's, ecological research was initiated in the LEF in collaboration with the Atomic Energy Commission. In 1965, the ITF's Annual Letter replaced the Caribbean Forester as the instrument to inform readers about ITF activities. In 1968, formal research efforts to save the endangered Puerto Rican Parrot, now confined to the Luquillo Forest, were started. In 1976, the Luquillo Forest was designated as a Biosphere Reserve. In 1980, the ITF, in conjunction with the Southern Experiment Station, initiated a continuous inventory of the island's secondary forests. In 1982, the ITF began biennial meetings of the Caribbean Foresters to discuss and publish forestry topics of regional interest. In 1986, LTER research was initiated in the Bisley watersheds of the Luquillo Forest, and in 1996, the El Portal Tropical Forest Center, Puerto Rico's gateway to the tropics, was opened to the public.

CURRENT PROGRAMS

A comprehensive program aimed at communicating the role of silviculture in managing national forests through educational means would be impossible without a full complement of other activities. Currently, the IITF (research designation) and the CNF (management designation) implement their programs on the same 11,300 ha forest in northeastern Puerto Rico with a combined staff of 17 professionals, 21 technicians, and 26 persons in administrative, clerical and support positions. Numerous cooperative agreements, grants, and volunteers extend the program's effectiveness.

Research

The IITF's research program is divided into four areas of emphasis: forest management, ecosystem management, wildlife management, and social ecology (Weaver 1996). The research unit description, approved in 1994 and scheduled to cover the next 5 years, concerns four research problem areas and involves 60 studies:

- Problem 1: Insufficient knowledge to effectively manage primary forests, or secondary forests following tropical disturbance and land use changes;
- Problem 2: Insufficient knowledge and predictive methods regarding the internal dynamics and external influences that affect atmospheric and hydrologic characteristics of forested tropical watersheds;
- Problem 3: Need to identify and characterize threatened, endangered, or sensitive tropical wildlife and to determine habitat characteristics and requirements for overwintering migrant birds in the Caribbean to develop ameliorative practices; and
- Problem 4: Need to quantify the economic and social values of American tropical forests.

The IITF also cooperates with the Forest Products Laboratory focusing on the utilization of tropical forest products and tropical mycology. Moreover, occasionally it sponsors or co-sponsors special projects or activities such as symposia or training programs.

The IITF research library subscribes to more than 100 journals and receives almost the same number of complementary serial publications through exchange with other institutions. The library also owns about 7,000 books on forestry and forest-related resources, houses a geographic section with about 20,000 brochures and reports, and contains numerous historical documents and maps. The library also posseses the "Silver Platter" CD-ROM on forestry literature and just inaugerated a WEB site to facilitate communication. The IITF research laboratory contains modern facilities and equipment for the analysis of soil and vegetation samples, and GIS work.

Resource Management

The CNF staff is responsible for the daily management of the Luquillo Forest which involves four major activities: customer service; property management; planning and design; and ecosystems programs. Special use permits, management of the El Portal Tropical Forest Center, grants and agreements, recreational programs (eg. Rent a Ranger, interpretation), trail maintenance and cleaning, environmental education, and the development of the forest management plan are included in the first three groups of activities. Ecosystems programs deal with visual and heritage resources, soil, water and air resources, wildlife, botany, threatened and endangered species, and timber stand improvement.

The CNF and IITF staffs, through a program of public involvement, developed a revised land and resource management plan for the Luquillo Forest along with its accompanying environmental impact statement (U. S. Forest Service 1994). Recently, the CNF assumed the management of the El Portal tropical forest center within the Luquillo Forest.

In 1995, the IITF State and Private forestry program managed 25 grants working closely with natural resource agencies in Puerto Rico and the U. S. Virgin Islands. Among the programs being implemented are: urban and community forestry; forest stewardship and stewardship incentive; economic recovery; rural conservation and development; wood in transportation; forest products conservation and recycling; nursery and tree improvement; forest resources management; forest legacy; forestry incentives; agricultural conservation; forest health management on cooperative and federal lands; rural fire prevention and control; state resource planning; and natural resource conservation and education.

Inventory and Monitoring

The IITF has several inventory and/or monitoring programs:

♦ Natural forest: monitoring natural regeneration and succession of key tree species on several sites in Puerto Rico and the U. S. Virgin Islands. Specifically, since 1943, on 20 permanent plots in different forest types in the Luquillo Mountains (Crow and Weaver 1977; Weaver, in press); from 1946 to the mid-1970's, on numerous sites throughout Puerto Rico (Weaver 1983); since 1983, on 16 plots in the Cinnamon Bay watershed of St. John, U.S. Virgin Islands (Weaver and Chinea-Rivera 1987); and since 1984, in the dry Guanica forest in southestern Puerto Rico (Murphy and Lugo 1986);

♦ Plantations: since the 1940's, periodic measurement of numerous species including several provenance trials throughout Puerto Rico and the U. S. Virgin Islands (Francis 1995);

♦ Arboretum: since 1960, the establishment and maintenance of an arboretum with more than 100 species, many with multiple subspecies and provenances, in forest conditions at 400 to 550 m in elevation in the Luquillo Mountains (Francis 1989);

♦ Parrots: since 1968, habitat research, and long-term monitoring of Puerto Rican Parrots (Snyder et al. 1987) and for shorter periods, other species including neotropical migrants (Wunderle and Waide 1994) and rare, endangered, or sensitive species;

♦ Secondary forest: since 1980, an island-wide inventory of secondary forest resources, updated in 1985 and 1990, and subsequently planned for re-measurement at 10-year intervals (Birdsey and Weaver 1982, 1987; Weaver and Birdsey 1990;

♦ LTER: since 1986, a long-term ecological research program dealing with flora and fauna in the Bisley watersheds of the Luquillo Mountains (Scatena 1989); and

♦ Big tree registry: since 1987, the maintenance of a registry of Puerto Rico's record trees to increase local appreciation for forest resources (Francis and Alemañy 1996).

The inventory and monitoring programs have provided valuable baseline information regarding forest structure, species composition, tree growth rates, and dynamics, especially in response to past human intervention and major climatic events such as hurricanes (Walker et al. 1991).

Wildlife monitoring within the Caribbean has indicated the proportions of local bird populations that are migratory and noted declines in neo-tropical migrants during the past quarter of a century. Continued monitoring may provide valuable comparative data for questions relating to human impacts on forests and wildlife as well as possible changes in global climate.

Demonstration

The Forest Service's organization and way of doing business (eg., research, management, state and private functions, and program administration) serve as a model for most visitors. Other demonstrations include:

♦ the IITF's continuous record system of 2550 studies;

♦ the maintenance and monitoring of numerous plantations (including mahogany line plantings) varying by species (or provenences), planting technique, age, and site;

♦ the maintenance of inventory and monitoring in primary and secondary forests, and restoration plots on abandoned lands;

♦ the CNF land management planning for multiple benefits;

♦ the El Portal tropical forest center; and

♦ the State and Private program with its complement of activities.

Partnerships

In 1995, the IITF had 63 active research grants and agreements with numerous institutions located in Puerto Rico, the U.S. Virgin Islands, the United States, and in foreign countries. The grants and agreements focus on a wide variety of tropical forestry issues including forest management, neotropical migratory birds, biodiversity, ecotourism, reforestation, wetlands, and the effects of deforestation on regional and global atmospheric composition.

Many scientists, managers, and students visit the island to conduct cooperative studies or observe activities on the national forest. Moreover, many of the IITF/CNF staff, working through the IITF's International Cooperation Program, participate on assignments in forest research, management or administrative activities throughout the neotropics. This frequently involves cooperation with foreign governments, international entities, Federal and Commonwealth agencies, private institutions, domestic and foreign universities, and non-government organizations whose influence may span regions or groups of countries. Among the more salient IITF cooperative activities during the past several years are:

♦ participation in overseas consultancies with the Forest Service, USAID, FAO, the World Bank, UNESCO, and other international entities to advance the interests of the United States at home and abroad;

♦ international cooperation with the World Bank in forest restoration of degraded lands throughout the tropics, activities aimed at the improvement of site productivity and

increasing timber and commodity production (Parrotta and Kanashiro 1995);

♦ cooperation with Brazil including global carbon and trace gas emission studies in Brazilian Amazon forests, activities aimed at the development of land management technologies that mitigate global climate change, water quality deterioration, soil erosion, and the loss of timber and non-timber species, and wildlife; and additional studies such as an English-Portuguese list of forestry terminology (Francis 1994) and a photographic guide to the trees of the Tapajos Forest (Parrotta et al. 1995);

♦ cooperative funding of forest inventories in the Maya zone of Mexico;

♦ assistance in the development of technical guidelines in support of the interests of the United States in the international arena including trade, migratory wildlife, and endangered species agreements (eg., CITES);

♦ cooperation with the Forest Department of Antigua-Barbuda in the development of a woody species list (Antigua: 286 species, 153 natives; Barbuda: 127 species, 65 natives) (Francis et al. 1994);

♦ cooperative funding of silviculture in mountain forests with the Forestry Department of Dominica;

♦ Peace Corps and host country collaboration through formal technology transfer plans (eg., Antigua, Dominican Republic, Grenada and Montserrat) in the design and development of nature trails and reforestation projects;

♦ Cooperation with the Park Service on the island of St. John, U. S. Virgin Islands, in forestry and wildlife research, and long-term monitoring;

♦ local cooperative research and management activities with the Puerto Rico Conservation Trust and other conservation groups;

♦ Collaboration with U. S. national forests as facilitators (shepherds) for six Sister Forest programs (pairings of U.S. National Forests and select national forests in neotropical countries); and

♦ numerous local, national and international advisory committes, among them: student thesis and university committees (eg., CEER), and interagency committees of the Commonwealth and Federal governments; national committees (eg. LTER); and international committees such as MAB, IUFRO, and the North Amerian and Latin American Forestry Commissions of the FAO. The staff also reviews proposals for ITTO and locally cooperates with the local DNER on reviews of management plans and legislation, and with Puerto Rican Conservation Trust on research and management programs on their properties scattered throughout the island.

Education

The IITF/CNF's educational program and clientele are diverse. The program includes research and publications, library activities, training and technology transfer, conferences and workshops, and other related activities. The clientele includes local, national and international forestry researchers, managers and administrators.

Publications. During recent years, the IITF research staff has published more than 50 scientific articles annually on forest management, ecology, wildlife, and social ecology. Staff members have also served on several journal editorial boards and reviewed numerous scientific articles for publication at home and abroad. Among the major efforts since the establishment of the IITF in 1939 are the following:

♦ 1939-1964: edit, publish and distribute to 2,000 collaborators, in Spanish and English, articles on forestry and related environmental topics in 24 quarterly volumes of the Caribbean Forester;

♦ 1939 to present: write an annual report (later called annual letter). Early editions were placed in the Caribbean Forester in both Spanish and English, but after 1964, the Annual Letter was published independently;

♦ 1949 to present: study and publish information on forest gradients, long-term growth, phenology, and fauna (eg., the Puerto Rican Parrot and other avifauna) in the Baño de Oro Research Natural Area (Weaver 1994);

♦ 1949-1993: publish the results of tree seed studies for more than 300 native and exotic species including collection, treatments, germination, and storage (Marrero 1949; Francis and Rodriguez 1993);

♦ 1950: publish the results of tree plantings on degraded lands (Marrero 1950a) and tree species adaptability on lands ranging from sea level to 1,000 m in elevation with rainfalls between 800 and 2,500 mm/yr (Marrero 1950b);

♦ 1949-1952: forest descriptions and the formulation of a land management plan based on climate, soil, topography, faunal requirements, scenic values, and past land uses and designating areas to be used for wildlife habitat, recreation, comparative research, timber production, and for the protection of primary forest ecosystems (Wadsworth 1949; 1951, 1952a, 1952b);

♦ 1963 to present: establish 1,275 ha of line planted mahogany at the management level (Weaver and Bauer 1986);

♦ 1964 and 1974: publish 2 volumes with dendrological and taxonomical descriptions, natural occurrence, uses, and common names for 750 native and exotic tree species of Puerto Rico and the U.S. Virgin Islands (Little and Wadsworth 1964; Little et al. 1974);

♦ 1966: summarize the results of eight herbicides for weed control in plantations (Hadley and Briscoe 1966);

♦ since 1968: investigate avifauna in Puerto Rico and elsewhere in the West Indies to determine population trends and the status of critical species (Snyder et al. 1987; Wunderle and Waide 1994) and their response to hurricanes Wunderle 1995);

♦ 1971-1973: map the ecological life zones of Puerto Rico and the U. S. Virgin Islands (Ewel and Whitmore 1973);

♦ 1972: summarize the results of fence post longevity based on four preservatives and two treatments for 6700 treated and non-treated control posts representing 70 tree species (Chudnoff and Goytía 1972);

♦ 1972: publish a summary of growth studies involving 15 conifer and 16 hardwood species for use in 60,000 ha of Puerto Rico's granitic uplands (Geary and Briscoe 1972);

♦ since 1975: publish 20 papers on long-term forest monitoring in the LEF and the Virgin Islands, some with records spanning more than 50 years (Crow and Weaver 1977; Weaver 1988, 1991; Weaver and Murphy 1990);

♦ 1979: publish a bulletin in English and Spanish on the use of 46 tree species in urban settings for Puerto Rico and the U. S. Virgin Islands (Schubert 1979);

♦ since 1981: edit the quarterly newsletter of International Society of Tropical Foresters for 2,000 subscribors in 128 countries;

♦ since 1981: draft 100 papers on indigeneous and exotic tree species in Puerto Rico and the U. S. Virgin Islands for the IITF's tropical silvics manual (including 8 species placed in the U. S. Silvics Manual) with information on habitat, life history, special uses, and genetics (Francis et al., in prep.; Burns and Honkala 1990);

♦ 1982: describe the storage and production of organic matter in tropical forests and their role in the carbon cycle (Brown and Lugo 1982);

♦ since 1982: publish several papers on the occurrence of tree species, forest structure and dynamics, and hurricane impacts for the forests of St. John, U. S. Virgin Islands (Woodbury and Weaver 1987; Park Science 1992);

♦ 1985: publish a volume on 150 vine species that grow in Puerto Rico (Acevedo-Rodríguez and Woodbury 1985);

♦ since 1987: edit and publish Acta Cientifica, a scientific journal for Puerto Rican science teachers;

♦ 1987 and 1991: publish a technical guide for nursery management (Liegel and Venator 1987) and growth and site relationships of Caribbean Pine in the Caribbean Basin (Liegel 1991);

♦ since 1988: maintain a registry of big trees in Puerto Rico;

♦ since 1988: research and publish about 200 papers on LTER in the LEF's Bisley watersheds beginning with a description of the watersheds (Scatena1989); and

♦ 1991: publish a list of 118 naturalized exotic tree species in Puerto Rico including information on where they are common, their environmental requirements (eg., rainfall and soil properties), and their estimated rates of spread (Francis and Liogier 1991);

Moreover, the IITF has collaborated with numerous other scientists in the publication of such works as:

♦ Puerto Rican woods (Longwood 1961) and Commercial timbers of the Caribbean (Longwood 1962), two volumes containing the physical and machining properties of 60 Puerto Rican timbers and 68 Caribbean timbers with commercial potential, cooperative research with the Forest Products Laboratory in Madison, Wisconsin;

♦ A tropical rain forest: a description of research beginning in the early 1960's and culminating in 1970 with a compendium of information in 111 research papers totaling 1644 pages (Odum and Pigeon 1970);

♦ Journal of the Arnold Arboretum: the introduction by Howard (1968) was the first of 17 articles published from 1968-77 on the climate, soils, forest resources, and related topics in the LEF's dwarf forest; and

♦ The parrots of Luquillo: a history of 20 years of parrot research in the LEF published in 1987 (Snyder et al. 1987).

Library. The library staff hosts from 600 to 700 international and local visitors annually. Most library users are from Federal and Commonwealth government agencies or students and teachers from local universities and highschools. The library also answers an average of 16,000 information requests annually, half of which are from Puerto Rico. The IITF's Annual Letter is interchanged for research reports with about 200 research units worldwide.

Training and Technology Transfer. Since 1939, the IITF staff has hosted innumerable visitors and interns from all over the tropics. Recently, volunteers have worked with the research staff for periods ranging from a few weeks to a year. Formal training programs have been presented for several groups or individuals, among them the following:

♦ from 1953 to 1983, the presentation of 20 bilingual international forestry short courses with some of the attendees later being promoted to leadership positions within their respective governments;

♦ 1962-63, formal 3-month programs of graduate study in tropical forestry and silviculture for 30 forestry students from all over the United States;

♦ from 1975 to the present, the occasional development of short training programs for Peace Corps volunteers, mainly in Caribbean Basin countries; and

♦ from 1980 to the present, participation on student theses comittees and as lecturers in university courses locally, in the U. S., and internationally.

In addition to the formal training programs mentioned above, the CNF staff hosts 700,000 visitors annually within the Luquillo Forest. Among the major attractions are wildlife, mountainous scenery, riparian areas, and several trails with interpretative signs. Tours are available on request.

Recently, the El Portal tropical forest center opened to the public. The 930 square meters of floor space is divided into classrooms, conference rooms, laboratories, and three large exhibition rooms. The staff of the Portal offers educational programs for students and holds workshops for school teachers. Training modules highlighting Puerto Rican tree species and forests, human benefits derived from forests,

Table 1.—Symposia and conferences held in Puerto Rico and sponsored by or in collaboration with the International Institute of Tropical Forestry

Date	Topic
1986	Conference on the Management of the Forests of Tropical America[1]
1987	Workshop on Caribbean Wetlands
1988	USAID Mangrove Workshop
1989	IITF Golden Anniversary Symposium[2]
1991	Seed Workshop for Nursery Managers
1991	USFS-NASA-FAO Workshop on Remote Sensing[3]
1993	30th Anniversary of the Association for Tropical Biology (ATB)
1993	International Symposium on Tropical Montane Forests[4]
1996	Horticulture Conference
1996	Big-leaf Mahogany: ecology, genetic resources, and management[5]

[1]Figueroa Colon et al. 1986.
[2]Lugo and Lowe 1995.
[3]Gillespie 1991.
[4]Hamilton et al. 1993.
[5]Proceedings in preparation.

Table 2.—Host countries and topics for the Biennial Caribbean Foresters' Meetings

Host country location Dates	Conference themes[1]
Castries, St. Lucia May 24-28, 1982	Forestry in the Caribbean
Kingstown, St. Vincent March 19-23, 1984	Watershed management in the Caribbean
Pointe-a-Pitre, Guadeloupe May 19-23, 1986	Forest recreation in the Caribbean Islands
Roseau, Dominica April 5-9, 1988	Wildlife management in the Caribbean Islands
Port-of-Spain, Trinidad May 21-26, 1990	Wetlands management in the Caribbean and the role of forestry in the economy
Fort de France, Martinique July 20-22, 1992	Towards sustainable forest resource management in the Caribbean
Kingston, Jamaica July 20-24, 1994	Economics of Caribbean Forestry
St. Georges, Grenada June 2-6, 1996	Protected areas management

[1]All conferences have been published as proceedings except the last which is in press.

and conservation issues have been developed to serve an estimated 30,000 students per year. A training program aimed at improving forest management capabilities will also be offered for forest managers from the Caribbean and Latin America.

The CNF also hosts the YACC and YCC programs during the summer months. Occasionally, it sponsors an open house on the forest or exhibits at shopping malls where up to 20,000 visitors may become familiar with Forest Service programs. Other activities include judging at local science fairs, participation in highschool career day activities, and presentations on local radio and television programs.

Conferences and Workshops. The IITF has hosted several different activities both locally (Table 1) and internationally (Table 2). Attendance at these meetings ranges from 25 to 300 or more with representation from numerous countries throughout the world. Proceedings of locally sponsored meetings are always published.

SUMMARY

The IITF has a 58-year history of serving its forestry clientele—the domestic interests of the peoples of Puerto Rico, the U.S. Virgin Islands, and the United States, and the foreign concerns of the peoples elsewhere in the Caribbean Basin and Latin America. Research, resource management, forest inventories and monitoring, demonstration, partnerships, and educational activities have been an integral part of its domestic and international programs.

Program diversity has been one critical element in program success. Currently, this diversity includes research, management, international cooperation, and state and private forestry. Another important element has been the long term coordination of forest research and management objectives within Puerto Rico and the U.S. Virgin Islands. These program attributes, diversity and coordination, along with the library and the recently completed El Portal tropical forest center, have contributed to a viable forestry program and have facilitated the communication of silvicultural benefits to domestic and international audiences.

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Communicating the Value and Benefits of Silviculture through Partnerships and Collaborative Stewardship

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Abstract.—Opening comments to this session share observations on the current management climate within the USDA Forest Service. Partnerships and collaborative stewardship as agency philosophy are discussed. Silviculturists roles, as scientists and managers are compared, and the need for internal and external cooperation stressed as we strive to meet forest stewardship goals.

INTRODUCTION

The current management climate affecting the Forest Service is one of great challenge and opportunities. The Forest Service is striving to implement a major shift in management approach towards sustainable resource management. It is doing so under scrutiny of Congressional appropriations committees that are struggling to understand what this change will mean in terms of an agency budget formed largely of timber management funds. The April, 1997 Government Account Office Report "Forest Service Decision-making: A Framework for Improving Performance" reveals an agency wide lack of accountability for decision-making and associated low return on investment of planning dollars. This problem, also known as "analysis paralysis" has created an agency "debt" caused by investment of dollars and expertise without return in the form of positive management action on the ground. Clint Carlson, Team Leader for the Bitterroot Ecosystem Management Research Project, describes this debt as "forests susceptible to fire, disease and insects" that affect both amenity and commodity benefits, and "over 3 billion dollars annually to run an agency whose productivity is declining dramatically." Add to this the increasing demands being placed on limited forest resources worldwide(Carlson, 1997).

It is important to note that although Congressional interest is intense, many members of Congress have very limited awareness of the mission of the Forest Service, which reflects a limited awareness among the Americans they serve.

Meanwhile, Forest Service resource managers are working harder than ever, applying their professional expertise to define and achieve the agency's land stewardship and public service mission. The Forest Service continues to expand its contributions in International Forestry, State and Private Forestry programs, Research, and in National Forest Systems. However, the agency faces difficult times as an agency, with many of us experiencing challenges in forming ecosystem based plans and projects, and equal difficulty in implementing them on the ground. Polarized interests, prolonged analysis, changing techniques, and funding uncertainties all contribute to today's management climate. There is a maxim that states "there is opportunity in chaos." Applying agency energy to building a stronger constituency and support base for sustainable resource management is one such opportunity to speed achievement of sustainable management goals.

PARTNERSHIPS AND COLLABORATIVE STEWARDSHIP

Webster's II defines a partnership as "an association with another or others in a common activity or interest." If one collaborates, one is "working together in a joint intellectual effort. Stewardship is defined as "the state of managing an others' property, finances, or other affairs." Critically examining these definitions is important to understanding what is meant when Chief Dombeck calls the agency to "Collaborative Stewardship." Collaborative stewardship gives contextual meaning to our responsibility for managing America's forests and supporting sound stewardship throughout the world. Chief Dombeck adds additional context in his definitions of collaborative stewardship as our agency resource management philosophy. It is achieved by "listening to all our constituents and by living within the limits of the land" and through a "commitment to healthy ecosystems and working with people on the land (Dombeck, 1997).

There is no cookbook for collaborative stewardship. It requires scientist and managers to purposefully seek ways to work together with each other, and with the public, in defining limits to the land and defining sustainable uses of the land. This happens most effectively with people getting together on the land in communities where programs are implemented.

ROLES OF SCIENTISTS AND MANAGERS

Effective collaboration begins with an understanding of what each can contribute to developing management objectives for the land. Individuals and interest groups bring their needs, concerns, and expertise. All, regardless of what draws them to the table, have something to contribute. So, too, with scientists and managers. It is important for scientists and managers to know their respective roles. Tom Mills, Pacific Northwest Station Director, lists the following characteristics of **scientists** as they do their jobs in support of managers and decision makers:

- retain independence
- quantify risk
- do not define appropriate levels of risk
- accomplish quality control
- conduct consistency checks between decisions and scientific information considered - was science interpreted correctly? were risks associated with decision understood, considered, and revealed?
- do not take positions

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He also describes the primary roles of **decision makers and managers:**

- clarify management goals
- clarify management questions
- determine levels of risk tolerance
- understand science findings and their implications for management
- challenge scientific logic, if faulty
- do not challenge science because the results are uncomfortable
- do not ask scientist to take or to support a position (Mills, 1997)

Collaboration based on an understanding of these roles can result in highly effective application of science in decision making. Both scientists and managers need to periodically scrutinize their work processes to determine if their interactions with the "other" are contributing to effective application of science in land management decision-making. It is important for members of the public to understand these ascribed roles to enable them to better work with local Forest Service officials.

CHALLENGES AND OPPORTUNITIES

The Silviculturist as Integrator. In collaborative stewardship, all agency professionals must serve as teachers before they can guide and contribute as scientists and managers. Silviculturists have many challenges and opportunities to conquer during this transitional period in the Forest Service. As experts of the dominating feature of forested landscapes, silviculturists are in a powerful position to be leaders in building internal partnerships and external support. The job of the silviculturist must, now more than ever, go beyond an exclusive interest in growing and harvesting trees. Silviculturists can champion biodiversity and sustainability and define ways to achieve it through their role in managing the structural backbone of these ecosystems. To do this, silviculturists need a understanding of the relationships between vegetative cover and soil stability, water quantity and quality, species diversity, fire risk and air quality. When silviculturists speak beyond the trees, they can demonstrate to the public how vegetation management can positively affect individual ecological components as well as the whole. As public understanding grows, so does increased support for on the ground management.

Aiming for the Middle. About 10 percent of those involved in natural resource management issues are controlling 90 percent of the debate. While it is important to understand the positions and desires of polarized interests it is prudent to quickly realize how impossible it is to satisfy opposite poles. Line officers with support from interdisciplinary teams, must develop public involvement goals that capture the interest of the community members who fill the space between the polar opposites. As more local citizens become aware of the Forest Service mission and how it relates to their communities and lives, there is a greater chance for management choices and decisions to receive broader support, and greater success in of implementation.

Dealing with Uncertainty and Risk. "We don't know enough." This is a statement frequently heard both inside and outside of the agency. As we manage landscapes for biological diversity and long-term sustainability of ecosystems, we do so without the extensive benefit of past experience. Forestry and silviculture have a long history of on the ground management and research, when compared with other resource areas. Once again, silviculturists have an opportunity to ease uncertainty and risk by examining past activities in the context of landscapes and other resource effects.

The antidote to uncertainty lies in identifying acceptable levels of risk with existing information and developing monitoring processes to closely track effects of implementation over time. Through the relationships developed with collaborative stewardship, Forest Service scientists and decision-makers can describe uncertainty and commit to monitoring after decisions are made. We then can demonstrate to the public that conscientious thought has gone into decisions, and that risks are not ignored. This approach must become standardized because it, too, will lead to increased understanding and support of management decisions and result in implementation. The unfavorable alternative is an extended analysis process that consumes resources with delayed or non-existent results.

Measuring Results

Here are a few indicators for identifying goals for and evaluating collaborative relationships:

- **Attentive listening** - is everyone involved given the chance to be heard?
- **Shared values** - have individuals identified shared values enable them to commit to the relationship?
- **Responsiveness** - have participants made adjustments and trade-offs to accommodate shared values and important requirements?
- **Celebrate accomplishments** - are there issues that were successfully resolved or activities successfully accomplished?

Collaborative stewardship provides an important opportunity for promoting the values and benefits of silviculture. Scientists and managers can use it as the basis for effective working relationships with each other, decision-makers, interdisciplinary teams, and communities. Just as there is no cookbook for designing collaborative stewardship, there is set process for measuring results. It is a journey, it is about relationships, and it is about action on the ground. Collaborative stewardship is not a quick-fix management initiative. It takes time to develop, as with any lasting relationship.

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Demonstrating Appropriate Silviculture for Sustainable Forestry in Central Siberia: A Russian - American Partnership

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Abstract.—A joint Northeastern Forest Experiment Station - Eastern Region team is working with Russian counterparts on a Forests for the Future Initiative in the Krasnoyarsk region of central Siberia. Russian team members include scientists from the Sukachev Institute of the Russian Academy of Sciences, managers from a number of units of the Federal Forest Service of Russia, and the directors of a logging and sawmilling enterprise. The goal is to establish a pilot project demonstrating principals of forest conservation and sustainable development. Applying silvicultural treatments appropriate for the forests of the region is a key element of the program.

INTRODUCTION

In 1993, a team of scientists and managers from the USDA Forest Service's Northeastern Forest Experiment Station and the Eastern Region was established to work with Russian counterparts on a Forests for the Future Initiative (FFI) in the Krasnoyarsk Krai (Region) of central Siberia. The goal of the FFI program is to establish pilot projects to demonstrate the principles of forest conservation and sustainable development. The first phase of the project in Krasnoyarsk was to provide geographic information system (GIS) capability at the field level in Siberia. Begun in 1995, the second phase was to establish demonstrations of sustainable forestry practices in areas scheduled for harvesting. This paper will present background, progress, and plans for Phase Two.

Currently, members of the American team include scientists from the Northeastern Forest Experiment Station, and managers from Region 9, Region 1, and the Washington Office of the Forest Service. Russian team members include scientists of the Sukachev Institute of the Russian Academy of Sciences, managers from a number of units of the Federal Forest Service of Russia, and the directors of a state-owned logging and sawmilling enterprise.

In preparation for Phase Two, the American team visited Siberia in 1995 to become familiar with the ecology of the region and the state of research in the area. We returned to Siberia in 1996 to witness harvest operations in the area. Also in 1995 and 1996, several delegations of Russian researchers, managers, and industrialists visited northern New England and the Lake States to view our long-term research and operations on national forest and industrial forest lands, and visited California and Montana to learn about prescribed burning.

AN OVERVIEW OF KRASNOYARSK KRAI

Krasnoyarsk Krai is in the Asian part of the Russian Federation and occupies 233 million ha or 13.6 percent of the country's territory. The krai lies between 51° and 81° N, and 78° and 113° E, and includes the geographic center of Russia. Its southern boundary is the Sayan Mountains and its northern, the Arctic Ocean. Elevation ranges from 100 to 3,000 m above sea level. In the past, many political exiles, including Lenin, were sent to the region; today its population is about 3 million people, most living in cities. The first democratic elections in the krai were held in 1993.

The Yenisei River, one of the world's largest with a total length of more than 4,000 km, flows through Krasnoyarsk Krai. It starts in the Sayan Mountains and flows north to the Kara Sea, dividing east and west Siberia. The two largest hydro-electric stations in Eurasia are on the Yenisei. With its many tributaries, the Yenisei forms an important transportation network for goods and passengers. One of its tributaries, the Angara, is the outlet of Lake Baikal. Although the rivers are extremely important for transportation within the region, they are of limited value for exporting goods because the outlet is to the Arctic Ocean. The Trans-Siberian Railway crosses the Krai; however, distances to commercial centers are vast. In a direct line it is 3,200 km west to Moscow and 3,000 km east to Vladivostok.

The Krasnoyarsk Krai takes its name from its capital city. Located on the Yenisei, the city of Krasnoyarsk, which loosely means "beautiful red riverbank," was founded in 1628 by a nobleman from Moscow and some 300 Cossacks. It is an industrial, cultural, and educational center with a population of nearly 1 million people.

The area within Krasnoyarsk Krai chosen for demonstrating sustainable forestry is in the Predivinsk lespromkhoz (a timber enterprise) within Bolshoya Murta leskhoz (equivalent to a national forest in the United States). Bolshoya Murta is also the name of a village and the surrounding administrative district, similar to a county. Predivinsk is a village of about 5,000 people on the east bank of the Yenisei River, east-northeast of Bolshoya Murta. The people who live in the village are entirely dependent on the timber enterprise for their livelihoods. They work either in the sawmill, as loggers, or in support of those activities.

THE FORESTS OF BOLSHOYA MURTA

The Bolshoya Murta leskhoz (approximately 57° N, 93° E) is about 450,000 ha in size and 93 percent forested. The climate is continental with a mean annual temperature of 1.0° C, and maximum and minimum temperatures of 36.9°

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and -48.0° C, respectively (E. Vaganov, personal communication). Precipitation averages 406 mm per year, the growing season averages 146 days, and soils typically freeze to a depth of 172 cm. The area was not covered by the last continental glacier.

The leskhoz is divided by the Yenisei River. The western part of Bolshoya Murta is southern taiga and subtaiga forest-steppe transition. These sites are quite flat. Soils are Podzolic (Alfisol and Spodosol) and Chernozem (Mollisol). The eastern part is mountain taiga forest. The mountains are not large and only moderate slopes are encountered. Soils there are also Podzolic. The area is south of the permafrost zone.

The southern taiga and mountain taiga forests are comprised of "dark coniferous", "light coniferous", and hardwood stands. Except for scattered trees occasionally harvested for local use, these stands have never been logged. However, because of natural disturbance, average stand age is only about 91 years (E. Vaganov, personal communication). Nevertheless, coring of individual trees when we were there indicated some more than 200 years old. Furthermore, many of the stands we visited had the appearance of being uneven-aged. Trees of the forest-steppe transition are mostly birch, *Betula*, and pine, *Pinus*.

Although they are at higher latitude, dark coniferous stands found in Bolshoya Murta are strikingly similar to spruce-fir, *Picea-Abies*, forests of eastern North America. Siberian spruce, *P. obovata*, is similar to red spruce, *P. rubens* Sarg., so common in Maine and Atlantic Canada, and to white spruce, *P. glauca* (Moench) Voss, which is common across the northern United States and Canada. Siberian fir, *A. sibirica*, is similar to balsam fir, *A. balsamea* (L.) Mill. Although it is a stone pine (i.e., 5-needle fascicles, short-winged or wingless seeds), Siberian pine, *P. sibirica*, (called cedar by the local people) seems to have an ecological niche much like eastern white pine, *P. strobus* L., in mixed conifer forests of eastern North America. These are all relatively tolerant species and the stands tend to have multiple cohorts. Natural disturbances include insect epidemics, wind, and fire. After stand-replacing disturbance, dark coniferous stands are followed by the region's only large hardwoods, birch, *B. pendula*, and aspen, *Populus tremula*.

Light coniferous stands of Scotch pine, *Pinus sylvestris* L., are usually even-aged and appear similar to natural stands of red pine, *P. resinosa* Ait., in the Lake States. With increasing latitude, Siberian larch, *Larix sibirica*, progressively replaces pine in light coniferous stands. However, in the area where we are working, pine is much more common than larch.

Essentially all land in Russia is owned by the state. Forests are classified into three groups according to function. Group I forests are protected. Degree of protection varies by sub-group but, in general, only light partial salvage and sanitary cuts are allowed. Protection is provided to ensure a presence of Siberian pine in the forest, for riparian zones, shelter belts along roads, and at forest-town interfaces. In Bolshoya Murta, 11.7 percent of the forest area is Group I (E. Vaganov, personal communication). Wood from Group II forests can be harvested for local use, but these forests also have defined protective functions. Only 3.2 percent of the forest area of Bolshoya Murta is Group II. Forests in Group III are subject to industrial wood harvesting and the wood can be exported outside the region. These forests are supposed to be protected from fire and regenerated after harvesting. In Bolshoya Murta, 85.1 percent of the forest area is Group III, and thus available for industrial management.

Various elements of the Federal Forest Service of Russia are responsible for inventory, protection, and management of the forests. Under Soviet rule, state-controlled industrial enterprises harvested and processed timber. Since then, many of the enterprises have been privatized. The enterprise located in Predivinsk, however, remains state-owed, under the direction of an appointed official. Like the few other state-owned enterprises in non-strategic industries, the Predivinsk Lespromkhoz operates as an independent unit.

Because of the current state of the economy in Russia, operating funds for federal agencies are extremely scarce. To maintain a viable organization, the Federal Forest Service resorts to innovative methods to raise revenue. While harvesting and processing are generally performed by industry, the Federal Forest Service is responsible for thinning and salvage operations, the income from which they can keep. The organization also keeps some of the money collected in fines levied for violating forest statutes.

CURRENT SITUATION

Silvicultural treatments in the Soviet Union were mandated based on forest type, stand structure, slope, and whether the site had sufficient advanced regeneration of valuable species. The same or similar rules still apply. However, since the breakup of the Soviet Union, these rules are not strictly enforced for a number of reasons, both economic and political in nature.

Russian partners in this project include ecologists, silviculturists, and fire behavior scientists from the Sukachev Institute, and managers from the Federal Forest Service at levels equivalent to Region, Forest, and District in the USDA Forest Service. We also work with members of the aerial fire suppression branch, which is separate from forest management. The director of the Predivinsk lespromkhoz and key members of his staff are also active participants. These Russians are all well trained and highly professional. They understand the ecology of their forests and how they should be managed. However, our Russian partners face severe economic and cultural barriers to implementing appropriate silviculture. Markets within the krai are limited and access to export markets is poor owing to the vast distances involved. The agencies represented by the partners in this project do not encourage dialogue between their personnel, probably a legacy of strict centralized control. That culture may also explain why silvicultural treatments are mandated and not prescribed on a site-specific basis.

Dark Coniferous Forest

In the Predivinsk lespromkhoz, tracts of dark coniferous forest are clearcut with little concern for regeneration. Harvesting is in 50-ha units using tracked feller-skidders. See Folkema and Holowacz (1985) for detailed descriptions of Russian logging equipment and practices. This equipment has several limitations: the operator can only harvest trees to the left; the boom reach is only 5 m; and trees cannot be lifted once cut—so tops are dragged across the site before the butt of the tree is placed in a bunk at the back of the machine. Furthermore, skidding progresses in 5-m wide strips across the harvest unit with each skid trail being the previously felled strip. Thus, the whole unit is covered by skidding and all advanced regeneration is destroyed. If artificial regeneration was an option, such harvesting might be acceptable. However, there is neither nursery capacity nor infrastructure to ensure that all harvest units get planted, and there is no funding available to release established conifer seedlings from hardwood competition.

Before mechanized harvesters were available, trees were felled by hand crews using chainsaws and moved to landings by cable skidders. That operation protected advanced regeneration. Paradoxically, even though the economy is poor, loggers in the area are no longer willing to fell trees by hand. The reason given for this anomaly was an unacceptably bad safety record for hand-felling operations. Yet, this is a concern that could be overcome with proper training. Perhaps the view that technology is a panacea for the current production slump and the possibility (however remote) to garner state funds for technological modernization are additional factors. Regardless, the director of the lespromkhoz feels compelled to continue mechanical harvesting and its resulting destruction of the regeneration.

In 1996, an experimental prescribed fire was used to reduce slash in a recent clearcut and to prepare the site for planting. That successful experiment was innovative. In Russia, fire is routinely considered destructive, and prescribed fire is a radical idea and virtually untested management tool. Only time will tell when, or if, prescribed burning will become an accepted practice.

Light Coniferous Forest

In Bolshoya Murta, most Scotch pine stands are in riparian zones or on slopes and, therefore, clearcutting is not permitted. However, we did visit one unit where pines had been harvested and strips of seed trees were left to regenerate the site. Pine stands are characterized by large volumes of high-quality, high-value sawtimber. In the only active operation we saw in such stands, individual trees were selectively cut (i.e., high graded) using a feller-buncher. Because it was considered a thinning operation, the logs were milled and sold by the local unit of the Federal Forest Service (equivalent to a Ranger District on a national forest in the United States). Although the best stems were removed, the cut was light and the residual stand retained a high density of quality trees. Furthermore, the feller-buncher operator did an excellent job of protecting the residual stand from damage while cutting and maneuvering harvested trees.

We saw a number of pine stands with evidence of low intensity, understory wild fires. In each case, good stocking of seedling and sapling pines existed in the burned areas, suggesting that fire might be an effective way to establish advanced regeneration before harvesting the overstory. As in the dark coniferous forest, however, prescribed fire has not been considered a method for achieving silvicultural goals. Nevertheless, prescribed fire could have significant implications for regeneration and maintenance of pine stands.

ACCOMPLISHMENTS AND PLANS

Since its beginning in 1993, this project can claim a number of accomplishments. Communications among all the partners are improving, and there is a strong sense that what we are trying to accomplish is extremely important. Undoubtedly, the greatest accomplishment has been bringing together the various agencies responsible for inventorying, protecting, managing, and utilizing the forests to work toward a common goal. Phase One, developing local capacity to build, maintain, and use GIS technology is operational and nearly complete. Managers of the forests around Bolshoya Murta have been authorized to experiment with treatments other than those normally prescribed by rule; the prescribed burn in 1996 is the first attempt at such innovation. Exchange visits between Russian and American partners have improved our understanding of each other and of our respective forests. These exchanges have shaped our annual work plans, infusing this project with a high degree of flexibility.

We have a number of objectives for the future. Within the next year, GIS technology should become available to the lespromkhoz, thus completing Phase One. Under Phase Two, we have two immediate objectives. One is to plan and conduct a site preparation underburn in a light coniferous stand to demonstrate the potential of fire to enhance natural regeneration of pine. The other is to conduct a trial harvest designed to protect some advanced regeneration in a dark coniferous stand using existing mechanical harvesting equipment.

The proposed harvest will cut 5-m wide skid trails in the conventional way, alternated with 5-m strips where trees will be cut and removed while providing some protection for advanced regeneration. Regeneration will be lost on the skid trails and not fully protected on the adjacent strips, but any regeneration saved is an improvement over present practice. This logging method is technically feasible using existing equipment, but is somewhat more difficult operationally. The director of the lespromkhoz is skeptical about the economics of the method but willing to try it as a demonstration. Over the longer term, we hope to encourage harvesting equipment manufacturers to demonstrate their machines in the region. Under similar terrain and forest conditions in the industrial spruce-fir forest of Maine and elsewhere, state-of-the-art feller-bunchers operating on designated skid trails do a good job of protecting advanced regeneration.

To its credit, this project has succeeded in generating a series of quick accomplishments. We hope that continued successful demonstrations of silvicultural techniques will lead

to a willingness to consider a longer term approach and integrated planning. We would like to identify some areas well before they are scheduled for harvest and prepare a thorough prescription. The evaluation would consider the state of advanced regeneration and recommend appropriate prescribed fire and cutting methods to control the composition and density of the future stand. In conclusion, the Russian-American partnership has tangible accomplishments and the vision needed to develop appropriate silvicultural prescriptions to help sustain the forests of Siberia for the future.

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The Blue Mountains Natural Resources Institute: Partnerships that Demonstrate the Role of Silviculture in Forest Management

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Abstract.—The research program of the Blue Mountains Natural Resources Institute (BMNRI) aims to understand the ecological effects of current management practices. In forest systems, this amounts to silvicultural research. We describe how the BMNRI fosters partnerships to carry out and showcase silvicultural research leading to information that allows assessment of economic/environmental tradeoffs. We also describe how partnerships are fostered not only to undertake research, but to encourage adaptive management. The BMNRI plays a unique role as a facilitator of relationships among managers, scientists, and the public, and has a structure ideal for demonstrating the role of silviculture in forest management.

INTRODUCTION

Although silviculuture has evolved into a multidisciplinary practice, to much of the public it still implies a focus on tree growth and timber production (O'Hara et al. 1994). While wildlife biologists have acknowledged the central role of silviculture in maintaining habitat (Thomas et al. 1979), reflecting the view that silviculture is the primary tool for objectives that require active management, many professionals in the Forest Service and elsewhere remain suspicious of a tree-focused agenda of silviculturists when it comes to making forest management decisions. The best way to change these perceptions is to demonstrate on the ground the role played by silviculture for implementation of a variety of management objectives. With an agenda to research the effect of management practices on ecological processes, the Blue Mountains Natural Resources Institute (BMNRI) is ideally poised to demonstrate this role.

The BMNRI was chartered in 1991 with a mission to "enhance the social and economic benefits derived from natural resources in the Blue Mountains in an ecologically sustainable manner." A small professional staff employed by the U.S.D.A. Forest Service is given advice by an approved Federal Advisory Committee, consisting of 24 members representing local, state, and federal government, academia, industry, environmental groups, and private citizens/ landowners. The BMNRI carries out its mission by brokering natural resources information through research, demonstration, and education. The staff relies heavily on its 80 partner organizations to accomplish its objectives—partners participate in planning or carrying out projects, circulating information, or conducting research. It is assumed that better scientific information has considerable value in dispelling myth and in providing a more solid foundation from which natural resources decisions are made. Issues that have information needs are first identified by the advisory committee and then are classified by the staff as needs that: 1) are a question of perceptions and/or values; 2) can be met by pulling together existing information; or 3) require new research. Value issues are best met by bringing people with opposing views together into forums, conferences, seminars, or workshops that illustrate the causes of people's perceptions. Information issues can in some cases be resolved by gathering information that already exists into syntheses or by simply making that information more available to the public and to land managers. If little or no information on a given issue can be obtained from the current literature, new research is fostered to fill the knowledge gap. This paper describes how partnerships are used to facilitate interaction among scientists and managers in undertaking operational research. The primary audience for BMNRI research is land managers, although the same information is made available to any interested group.

Once a knowledge gap is identified, research is planned that seeks information gathered in a management context, and that is integrated well enough to provide managers with the opportunity to explore tradeoffs. A strong technology transfer element completes the formula, because it is argued that for many contentious issues, managers require information in a more timely manner than is typical for most scientific publications. The BMNRI is currently involved in three main lines of research: relations between forest management and bird population viability, improved cattle distribution practices, and forest fuel reduction. We will illustrate the style and process of BMNRI research by focusing on how partnerships are fostered to facilitate research on fuel reduction. We hope to make it clear that not only is silvicultural expertise central to our fuel reduction research, but that the style the BMNRI uses to carry out the research is ideal for illustrating the role and value of silviculture.

THE FUEL REDUCTION ISSUE

Forest fuel reduction is currently a key objective for Forest Service managers in the inland West, primarily because fuel has increased due to 90 years of fire suppression (Everett 1993; Agee 1996). The concept is that if fuel of intermediate size classes (3-20 inches in diameter) can be reduced, the spread of wildfire and its intensity on any given site will also be reduced. Furthermore, because fuel levels are considered to be a problem for large areas of public land in the inland West (Gast et al. 1991; Quigley et al. 1997), fuel reduction needs to be accomplished at landscape scales, and this can realistically be done only with landscape prescribed fire (underburning) and by mechanical means (single-grip harvesters and their like). Although considerable research has focused on ecological effects of both of these practices (U.S.D.A. 1979; Kellogg et al. 1992; Monleon & Cromack 1996), and their relative costs are generally understood (Rich 1989; Kellogg et al. 1992),

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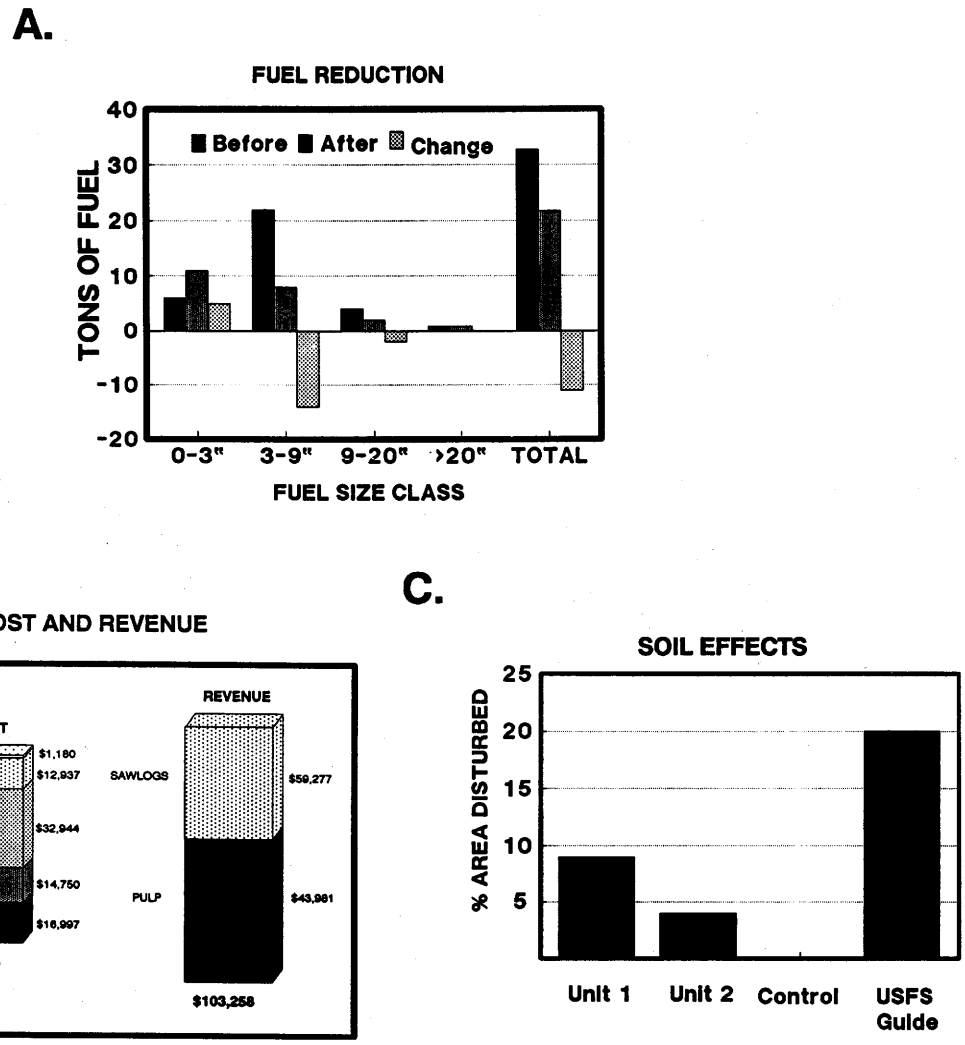

Figure 1.—Extent of fuel reduction, logging costs and revenue, and soil effects of the Deerhorn Harvest, July- August 1994.

few studies have measured both economics and environmental effects simultaneously under the same stand conditions. Only studies that are integrated in this way can provide information allowing assessment of economic/ environmental tradeoffs associated with either method, or that allows direct comparison of the two methods. The fuel reduction research program of the Blue Mountains Institute is designed to provide this kind of integrated information on comparative tradeoffs, such that managers will be able to better assess the relative benefits of alternative fuel reduction methods. In this essay, we will discuss a sequence of three fuel reduction projects that illustrate not only the style of integrated research used by the BMNRI, but the role of silviculture as well.

Integrated Research

The value of integrated research is well illustrated by the Deerhorn case study, which explored the economics and soil effects of implementing a fuel reduction prescription in a lodgepole pine stand growing on flat ground. Coordinated by the BMNRI, Deerhorn was a collaborative effort involving the La Grande Ranger District (prescription), Louisiana-Pacific (owners of the land), Eagle Trucking (yarding equipment), McClaren Logging Co., Oregon State University (operations and research), and the Forest Service PNW Station (fuel research). The prescription was designed to maintain overstory stand structure, significantly reduce fuel (down wood) in the 3-15 inch size classes, and still allow sufficient removal of material to keep the project economically feasible. A further constraint was that to adequately protect sensitive soils, a skyline yarder was used to retrieve material cut by a single-grip harvester. The flat ground at the Deerhorn site, coupled with the fuel reduction objective, placed considerable pressure on the silviculturist for a prescription that balanced all the needs. Undertaken over a 2-month period in summer 1994, the project resulted in significant fuel reduction in the 3-9 inch size class (Figure 1a), was economically viable (Figure 1b), and caused soil impacts well within the standards imposed by the Forest Service

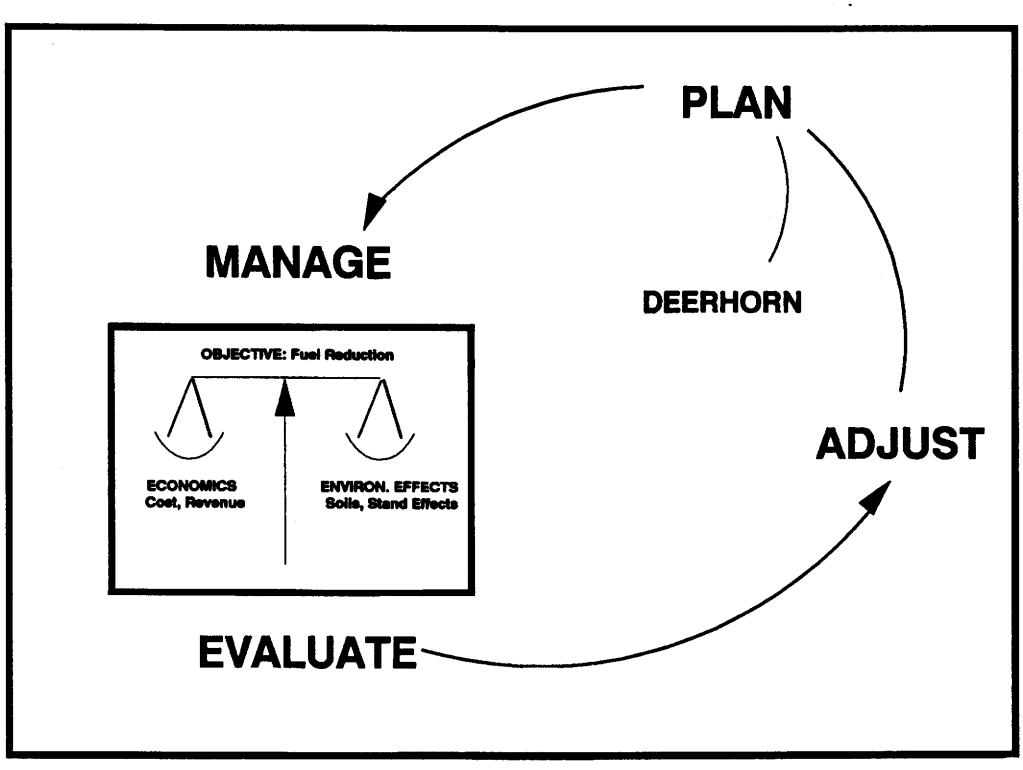

Figure 2.—Adaptive management cycle using an integrated management experiment as example of new information.

(Figure 1c) (McIver 1995). Results also indicated that fuel reduction of intermediate size classes may typically be associated with increases in the small diameter "flashy" fuel (< 3 inch) due to logging activity, thus increasing fire risk in the short term. Heavy soil impacts were all associated with gouging in the yarding corridors, due to inadequate log suspension during retrieval. Additional intermediate supports would be required to mitigate this type of damage. Finally, economic viability in this project was clearly associated with the percentage of the more valuable sawlog material removed, thus making the silvicultural prescription a critical link in the planning process (Brown & Kellogg 1996). This last point makes it clear that in order to implement a management objective that involves removal of low-value material, the role of the silviculturist is fundamental, especially under circumstances where both economics and environmental effects are of concern.

Adaptive Management

Results at the 50-acre Deerhorn site encouraged the La Grande Ranger District to move forward with plans to conduct fuel reduction at a larger scale. Deerhorn thus contributed to a cycle of adaptive management (Figure 2) in which lessons learned from one operation were used directly to plan the next operation. Because there is so much uncertainty surrounding the fuel reduction issue, and because many of the lands upon which fuel reduction is needed lie within municipal watersheds, information on how best to reduce fuels is at a premium. These are the kinds of circumstances within which adaptive management can best function. Decisions facing the La Grande Ranger District serve as a case in point. It has been estimated that in 1997 over 40,000 acres of the District required immediate treatment of low-value material to reduce the intensity and spread of wildfire. The highest-priority project turned out to be on Limber Jim ridge, a string of mixed-conifer/lodgepole pine stands on the divide between the Upper Grande Ronde River to the southwest and the Beaver Creek Drainage on the northeast, the latter being the principal watershed for the city of La Grande, Oregon. The idea was to create a "shaded fuel break," centered on the logging road that split the two watersheds, that could serve as an anchor point to station fire fighters in the event of a wildfire in the area. The fuel break would be about 7 miles long and 1000 ft. wide on either side of the road, with non-treated corridors in the draws to allow movement of forest-dependent wildlife. The challenge was to reduce fuel to less than half of the observed loadings by removing both standing and down dead wood, and to remove some of the smaller-diameter green trees to create growing space for the residual stand. Fuel reduction had to be accomplished economically, and without damaging the residual soils or stand, because the District wanted to demonstrate sensitive and feasible logging practices for fuel reduction on a larger scale.

Previous findings at Deerhorn and elsewhere had indicated that while the skyline retrieval system was ideal for protecting sensitive soils, it was expensive compared to more commonly used ground-based systems, especially on flat ground. Hence the BMNRI, working with the La Grande Ranger District, and a group of scientists at Oregon State University, the University of California, and the PNW Research Station, designed a fully replicated study to compare skyline retrieval of the low-value material at Limber Jim with an articulated, rubber-tired forwarder. The challenge for the silviculturist was to create a prescription that adequately balanced needs for wildlife and for fuel reduction, while providing enough sawlogs and pulp material to make the project economically feasible as a timber sale. Moreover, because stands differed substantially in species composition and structure, prescriptions had to be uniquely crafted to meet the fuel reduction objectives. The general guideline was that the only material removed would be down and standing dead material less than 15 inches in diameter, leaving at least 40 pieces per acre of residual down woody material.

Fuel reduction prescriptions were first implemented with a single-grip harvester in each of three stands at Limber Jim. Logs were cut to 16-foot lengths and stacked at regular intervals along corridors spaced 60 feet apart (the single-grip could reach 30 feet into the stand on either side of each corridor). Each unit was paired such that logs on one side were retrieved by skyline yarding, and on the other side by rubber-tired forwarding; efficiency (tons of logs retrieved per unit time) was compared for the two techniques. Fuel loads and soil bulk densities were measured both pre- and post-treatment; soil biota and residual stand damage were measured post-treatment. Although results are still preliminary, it is clear that fuel was reduced by between 50 and 80 percent, and forwarding appears to be the most economically feasible and environmentally attractive means to reduce fuel.

Although a primary objective of research at Limber Jim was to provide better information to managers on the efficacy of various logging systems for fuel reduction, it was equally important to demonstrate environmentally sensitive logging to the concerned public. Hence while operations and research were being carried out at Limber Jim, the BMNRI conducted several tours to demonstrate the efficacy of mechanical means to reduce excess fuel. Audiences included the general public; local, state, and national officials; environmental and industry groups; and land managers from the state agencies, BLM and the Forest Service. Additionally, a video illustrating the process of fuel reduction at Limber Jim, and the relationships among scientists, managers, and the public is currently being prepared.

The inclusion of a replicated scientific design within the Limber Jim project is one way in which adaptive management can be applied to accelerate learning. However, the kind of information needed to improve methods of fuel reduction is not only technical, but social as well. If the public is not confident of both the need for fuel reduction on federal lands, or the means to accomplish it, land managers will find it much more difficult explain and carry out their plans. Hence the BMNRI commissioned a study to survey the citizens of the Blue Mountains about fuel reduction needs and methods. Results indicated that of 560 citizens surveyed, most citizens felt that excess fuel needed to be treated, and the great majority were comfortable with the Forest Service using prescribed fire or thinning/removal to accomplish fuel reduction objectives (Shindler 1997).

Coordinated Silvicultural Research

The high degree of confidence expressed by the public for fuel reduction work motivated the BMNRI to acquire funds to carry out an ecological and economic comparison of prescribed fire and mechanical thinning/removal. The "Hungry Bob" project is designed to measure and illustrate how reduction of fuel by fire differs in quality and quantity from reduction by thinning and removal. The study will be carried out in ponderosa pine-dominated dry forest, where managers could conceivably use either method in any given situation. The project will require close interaction among several partners, including the Wallowa Valley Ranger District (which manages the site), scientists at Oregon State University and the PNW Station (labs in Corvallis, La Grande, and Seattle), and the contractor who buys the timber sale. At Hungry Bob, the challenge for the silviculturist will be to develop prescriptions for the thinning units that result in approximately the same levels of fuel as units that are underburned. This requires a close working relationship between the project silviculturist and the fire specialist. Measured variables include fuel levels, economics, soil effects (biology, chemistry, physics), and residual stand damage.

As for previous fuel reduction studies, the BMNRI will coordinate research, and serve as the liaison between research, management, and the public. Coordination of the players involved requires a substantial commitment of time and energy. Although coordination involves several activities conducted at key stages during the planning, undertaking, and reporting of a project (Table 1), the most important activities are raising funds to measure variables, and serving as the liaison between science and management. By taking over these two roles, the BMNRI can attract scientists to large-scale operational studies, which require substantial interaction with management and significant funding. By definition, research conducted within a management context will almost always generate information more useful to the manager, and thus the BMNRI plays an important role in applied silviculture research and adaptive management.

The approach described in this essay, in which relationships between managers, scientists, and the public are improved and tightened, is used for each project fostered by the BMNRI. Whenever managers and/or the public are allowed to identify and prioritize knowledge gaps themselves, and whenever scientists are encouraged to apply their expertise within a management context, the result will generally be that more useful information will be generated. Adaptive management in its more rigorous form can then become a reality, with its quicker turnaround of more reliable information.

Table 1.—Principal functions of BMNRI in coordinating integrated silvicultural research

FUNCTION	PLAYERS INVOLVED
Recognize information need	Managers, Partners, Public
Determine treatments/variables	Managers, Scientists, Public
Establish QA/QC measures	Scientists
Obtain funding to measure response variables	Scientists
Incorporate experimental design within timber sale contract	Managers
Liaison between managers and scientists	Managers, Scientists
Liaison between contractor and scientists	Contractor, Managers, Scientists
Oversee technology transfer, public relations	Management, Scientists, Public
Organize tours	Managers, Scientists, Partners, Public

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Monitoring the Mighty Duck Timber Sale: a National Forest - Conservation Organization - Research Partnership

Douglas M. Stone and Jay C. Strand[1]

Abstract.—Resource managers are seeking silvicultural solutions to a variety of ecological, economic, and social issues. These issues include maintaining healthy and aesthetically pleasing forests, and sustaining or increasing ecological diversity. To reestablish a conifer component, and thereby increase species diversity, the LaCroix Ranger District of the Superior National Forest planned to apply a reserve tree method (RTM) to reduce the density of aspen suckers and increase survival and growth of planted conifers. The Ruffed Grouse Society questioned widespread application of the treatment because of its potential impacts on early successional forest communities, and offered to help finance a study to monitor results of the RTM. Communication and cooperation among the LaCroix District, the North Central Station, and the Ruffed Grouse Society led to a three-way partnership and a study to monitor and evaluate the results in six stands for 10 years. This long-term partnership will provide mutually beneficial silvicultural information to all parties.

INTRODUCTION

At the 1993 National Silviculture Workshop, Bill Shands (Shands 1994) called for new, stronger relations between Forest Service Research, the National Forest System, and the public in implementing the complicated business of ecosystem management. He also listed, among his seven points of ecosystem management, the need for Forest Service silviculturists and others to help forge these new cooperative relationships. The only change we would suggest today would be to rephrase his last item to read: "No matter what your position description you have an **opportunity** to help forge these new, cooperative relationships!" This paper reports a case study that illustrates his points and shows how communication and cooperation led to a three-way partnership between the LaCroix Ranger District on the Superior National Forest, the Ruffed Grouse Society, and the Silviculture of Northern Great Lakes Forests Research Work Unit of the North Central Forest Experiment Station.

HISTORICAL BACKGROUND

The LaCroix District is typical of much of the public forest land of the northern Great Lakes region. Ecologically, most of the forest types are far different from those of a century ago. Depending on location, the pre-settlement species growing on medium to fine-textured soils of Minnesota, Michigan, and Wisconsin were predominantly shade-tolerant conifers including white pine, eastern hemlock, and northern white-cedar; and tolerant hardwoods dominated by sugar maple, red maple, yellow birch, and basswood (Albert 1995; Braun 1950; Coffman et al. 1983; Kotar et al. 1988). White spruce, balsam fir, white ash, and American elm were common associates. Without stand-replacing disturbances, the aspens occurred as minor associates (Braun 1950).

During the late 19th century, exploitative logging, initially of conifer species, created conditions for slash-fueled wildfires that swept over large areas of the region, destroyed advanced regeneration of the former species, and resulted in "brushlands" comprised predominantly of aspen suckers and stump sprouts of associated hardwood species (Graham *et al.* 1963). Effective fire control beginning in the 1920's permitted these stands to develop into the present-day second-growth forests dominated by aspen.

ECOLOGY AND MANAGEMENT

The aspens are intolerant, rapidly growing, short-lived species that regenerate by root suckers following removal of the parent stand (Perala and Russell 1983). Suckers exhibit more rapid early height growth than seedlings or sprouts of associated species, so they typically form the dominant overstory during the early and mid-stages of stand development. On medium and fine-textured soils, pure aspen stands are rare; most include a component of more tolerant, longer lived species typical of these sites in the absence of disturbance. Until the 1960's, aspen was considered a "weed" species and little was harvested, resulting in an unbalanced age class distribution. Over much of the region, a relatively small portion of the type is less than 30 years old and a much larger proportion is older than 60 years. On most land, aspen is managed for wood products or for a combination of fiber and wildlife habitat. Where wood production is a primary objective, the stands normally are harvested by a silvicultural clearcut of all species and the aspen is regenerated from root suckers. Presumably, the procedure can be repeated and the aspen maintained indefinitely (Perala and Russell 1983).

THE PROBLEM

Clearcutting at frequent (40- to 50-year) intervals to maintain single or dual-species stands in an early successional state conflicts with several of the objectives of ecosystem management (*e.g.,* Irland 1994). Ecologically, this interrupts natural successional processes and "resets the successional clock" (Mladnoff and Pastor 1993). Additionally, the extensive loss of the conifer component from much of the forest area of the Lake States region has caused concerns about ecosystem structure and function and the diversity and quality of wildlife habitat (Green 1995; Mladenoff and Pastor 1993). In this context, members of the Timber Management staff and the Wildlife Biologist on the LaCroix District had discussions about Desired Future Conditions on the District

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and possible ways to reestablish a component of native conifer species. Establishing these species on suitable sites was considered a first step toward increasing species diversity at the stand level. Moreover, total yields of mixed-species stands may well exceed those of aspen alone (Navratil et al. 1994; Perala 1977). Natural regeneration of most conifers on these sites usually is limited by lack of available seed sources. Development of planted seedlings frequently is hampered by competition from dense stands of aspen suckers, stump sprouts, hazel, mountain maple, and herbaceous species. Research on use of prescribed fire for conifer regeneration has begun, but results are not yet available.

APPROACH TO SOLUTION

Ruark (1990) proposed a reserve shelterwood system to convert 30- to 35-year-old, even-aged aspen stands to two-aged stands and concentrate limited site resources (sunlight, nutrients, water, and growing space) on fewer stems per unit area. The method has not been tested or validated, but offers several potential advantages at different spatial scales. At the stand management level, the additional growth of the residual trees would be concentrated on a few quality stems producing high-value sawlogs and veneer bolts rather than pulpwood. Likewise, inhibition of dense suckering could channel the carbohydrate and nutrient reserves in the parent root systems to fewer suckers and increase their early growth.

From a landscape perspective, the resulting two-storied stands are aesthetically more appealing to many people than are clearcuts. Maintaining partial stocking of the site may be less disruptive to normal hydrologic and nutrient cycling processes. Two-storied stands provide structural diversity that benefits some wildlife species (Green 1995; Ruark 1990). The portion of the timber volume retained will reduce the sale volume per unit area, but the Allowable Sale Quantity can be distributed over a larger area. This will accelerate development of a more balanced age class distribution and reduce the eminent "breakup" of overmature stands. From a silvicultural and forest health viewpoint, this is especially important to those Districts that are losing net volume from mortality due to stem decay.

THE MIGHTY DUCK SALE

The sale area is in the northern portion of the District, near Voyageurs National Park along the Canadian border. It includes about 70,000 cords of predominantly mature and overmature aspen in 38 stands, totaling 1,050 ha (2,600 ac) distributed over a 4,740-ha (11,700 ac) area. The Mighty Duck sale is the first of four within the sale area; it included 19,000 cords in 14 stands and was scheduled to be sold in fiscal year 1996. The original intent was to apply the RTM on about 40 percent of the sale area, or 420 ha (1,030 ac). This involved leaving about 25 to 40 dominant, vigorous aspen per hectare (10 to 15 per ac), at a spacing of 15 to 20 m (50 to 66 ft). The objective of the RTM was to reduce the overall density of aspen suckers per unit area. It was assumed that the reserve trees will inhibit suckering to a degree (Ruark 1990). The remainder of each stand will be clearcut, with natural sucker development.

The conventional logging practice in the area is mechanical felling using feller-bunchers, limbing at the stump to a 10-cm (4 in) top diameter, and tree-length skidding with grapple skidders. Except for a penalty for damage to reserve trees, no restrictions on skidding routes were specified. This normally results in skidder traffic over most of the site and helps to control the typically dense understories of hazel and mountain maple. Depending on soil texture and internal drainage, either white pine, red pine, white spruce, or a mixture of white pine and red pine seedlings will be planted between the reserve trees at about 900 to 1,200 seedlings per hectare (400 to 500 per ac). At typical survival rates of 70 to 80 percent, this will provide stands of predominantly aspen with a mixture of conifers adapted to the sites.

During the public comment period on the Environmental Assessment in April and May 1996, concerns were raised by several participants about: (1) the uncertainties surrounding application of the RTM treatment to a 420-ha (1,030 ac) area without prior experience to predict the results; (2) the loss of merchantable volume left in the reserved trees; (3) a potential reduction in the long-term volume of aspen; and (4) a perceived degradation of habitat quality for wildlife species dependent upon early successional vegetation. To address these concerns, the District reduced the area to 220 ha (535 ac) in the Decision Notice and Finding of No Significant Impact issued in June.

In July, the Ruffed Grouse Society further questioned application of the RTM on the grounds that it was unlikely to yield the desired results and that it conflicted with the Forest Plan, which specifies clearcutting and group selection for the aspen type. The District agreed to reduce the area to 60 ha (140 ac) in six stands selected to include both summer and winter logging and a range of soil characteristics and stand conditions. The Ruffed Grouse Society agreed to this proposal and offered to help finance a designed study to monitor and evaluate the results. A condition of the agreement was that an approved study plan would be in effect before the sale was offered. In mid-August the District contacted the Silviculture of Northern Great Lakes Forests Research Unit at the North Central Station to design and conduct a study to evaluate the results of the RTM.

THE RTM STUDY

The District gave our research work unit copies of Environmental Assessment documents, sale area maps, stand and site information, and land type phase descriptions and maps. We used the information to outline a preliminary study plan, and met with District staff in mid-September for an on-site examination of the stands. We then designed a study and prepared a study plan to document initial overstory and understory conditions; evaluate effects of summer *vs.* winter logging; assess logging impacts on site disturbance and soil physical properties; and to monitor the condition and vigor of the reserve trees, density and growth of aspen suckers and competing vegetation, and survival and growth of the planted conifers. The study will provide data on effects of season of logging; overstory density; site disturbance; distribution and depth of logging slash; competing woody and

herbaceous vegetation; and physical soil properties, sufficient to assess development of the regeneration. This information will enable us to evaluate the RTM, and perhaps, to develop preliminary management recommendations for establishment of mixed-species stands on similar sites. Study installation began in late September, and the Mighty Duck Sale was sold on schedule.

DISCUSSION

In our experience, communication and cooperation between the National Forests and silviculture research units in the Lake States have been excellent. However, implementing ecosystem management is changing silvicultural objectives, practices, inquiries and questions. Resource managers are seeking silvicultural solutions to a variety of ecological, economic, and social issues that include sustaining or increasing ecological diversity, maintaining healthy and aesthetically pleasing forests, and restoring fish and wildlife habitat (Kaufmann *et al.* 1994; Baumgras and Skog 1996). Silvicultural research has a long record of providing scientific information and guidelines for maintaining and sustaining productive forests; however our research has emphasized the production aspects of forest management (Loftus and Aune 1995). The complexity of ecosystem management challenges us to change the way we approach and carry out our silvicultural tasks; this means renewed responsibilities for silvicultural research (Loftus and Aune 1995). Research units may not have answers to all of your questions, but we are willing to work with you to find satisfactory answers, or at least to develop "first approximation" solutions.

The Mighty Duck sale and the RTM study illustrate the role of communication, cooperation, and partnerships in implementing ecosystem management. The District was seeking a silvicultural approach to increase species and structural diversity by reestablishing a component of native conifers. The philosophy of ecosystem management says that we can manage forest lands for their full array of values and uses, but this calls for changes in the traditional ways of managing resources (Loftus and Aune 1995). To meet its multiple use objectives, the District was willing to take an adaptive management approach and try a modification of a method that had not been tested nor validated. The Ruffed Grouse Society helped to place the uncertainties of the RTM in perspective, pointed out the need for monitoring and evaluation, and committed to share the associated costs. The partnership provided the Station an opportunity to initiate a study on establishment of mixed-species stands that is likely to require some on-the-ground adaptive management. Adaptive management provides an opportunity for silvicultural research to contribute to the implementation of ecosystem management (Loftus and Aune 1995). It also gives us reason to monitor results and evaluate outcomes of our guidelines and prescriptions. This will improve resource management activities incrementally as managers and scientists learn from experience and new scientific findings.

Although the study is still being installed, and logging has not yet begun, it illustrates how ranger districts, partners, and research units can work together for mutual benefit. The results will give the District information on whether or not the RTM applied to 60- to 70-year-old aspen stands is effective in decreasing sucker density and in facilitating establishment of native conifers. It will provide the Ruffed Grouse Society with data about treatment effects on development of aspen suckers and on wildlife habitat characteristics. The study results will enable us to evaluate the RTM in mature stands harvested in summer and winter, and depending on the outcome, to either develop preliminary management recommendations for similar stands and sites, or design a study to evaluate the RTM under a range of overstory densities in younger age classes. Either way, this partnership illustrates a "win-win-win" situation.

ACKNOWLEDGMENT

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APPENDIX

Common and scientific names of trees and shrubs.

Balsam fir (*Abies balsamea* (L.) Mill.)
Red maple (*Acer rubrum* L.)
Sugar maple (*Acer saccharum* Marsh.)
Yellow birch (*Betula alleghaniensis* Britt.)
Paper birch (*Betula papyrifera* Marsh.)
White ash (*Fraxinus americana* L.)
White spruce (*Picea glauca* (Moench) Voss)
Eastern white pine (*Pinus strobus* L.)
Bigtooth aspen (*Populus grandidentata* Michx.)
Trembling aspen (*Populus tremuloides* Michx.)
Northern white-cedar (*Thuja occidentalis* L.)
Basswood (*Tilia americana* L.)
Eastern hemlock (*Tsuga canadensis* (L.) Carr.)
American elm (*Ulmus americana* L.)

Mountain maple (*Acer spicatum* Lam.)
Beaked hazel (*Corylus cornuta* Marsh.)

The role of silviculture in the active management of riparian zone vegetation in the Oregon Coast Range: a partnership between researchers and managers

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Abstract. —Riparian plant communities are extremely diverse. Their structure and composition can affect fish and wildlife habitat, while trees and associated vegetation can provide sustainable sources of forest products. Management of riparian vegetation can greatly affect these values. Little information exists however, about the consequences of actively managing riparians to develop desirable habitat characteristics and enhance function versus setting aside areas as passively managed reserves. Management options are limited in riparian areas because of concerns for the protection of values provided by these sensitive areas.

Researchers and managers from multiple disciplines and agencies in partnership through the COPE (Coastal Oregon Productivity Enhancement) program are testing a variety of silvicultural treatment alternatives for active management of riparian areas. The partners collaborate to define needs, identify knowledge gaps, design and implement studies, and facilitate technology transfer. We are learning about the ecological consequences of active management within riparian reserve scenarios by developing and studying a range of active management and reserve options.

The studies provide a reference for managers, researchers, and the interested public to evaluate silvicultural alternatives in riparian areas. We have found in our studies that active management practices such as thinning, vegetation management, and tree regeneration are needed to establish conifers in hardwood and shrub-dominated riparian areas of the Oregon Coast Range. The establishment of conifers along with hardwoods is expected to maintain and enhance riparian structure, function, and productivity. Thinning to create canopy openings that allow 40% or more of full sunlight to penetrate through the overstory and reducing the competition from understory shrubs is necessary to successfully regenerate trees in the hardwood dominated-riparian areas of the Oregon Coast Range. Managers have adapted the findings into both demonstration and on-going operational riparian restoration projects. Cooperation through this partnership has resulted in adaptive learning and better understanding of the options and opportunities for riparian vegetation management, enhancement, and restoration.

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INTRODUCTION

Riparian areas in the Pacific Northwest have traditionally been used for sources of natural resources, settlement, agriculture, transportation corridors and energy (Malanson 1993). Current perspectives of riparian areas focus on the biological and physical functions and processes in riparian areas along with the traditional utilitarian uses. Examples of these functions and processes include habitat for wildlife; nutrient capture; filtering and cycling; the input of woody debris and sediments; provision of favorable microsite and microclimate conditions; and high quality water (Gregory 1997).

Riparian areas are critically important transition zones between the aquatic and upland terrestrial landscape. Frequent disturbances from flooding, landslides, and debris flows have created physically complex environments that are highly productive and capable of supporting a diversity of species. Healthy riparian areas and streams serve as reservoirs of biodiversity, animal habitat, corridors, clean water, wood products, food, special forest products, energy, and recreation. The diversity of riparian outputs often results in conflicts between different interest groups over the use of riparian areas. The biophysical complexity of the riparian landscape and the interactions between the aquatic, streamside, and upslope communities poses a significant management challenge for resource managers (Hayes et al. 1996). The influence of past management practices on aquatic dependent species (especially anadromous fish) have surfaced as one of the most significant challenges currently facing land managers in the Pacific Northwest.

The Northwest Forest Plan (Record of Decision, 1994) amended the Land and Resource Management Plans of federally managed forest lands situated within the range of the northern spotted owl (*Strix occidentalis*) in Washington, Oregon, and northern California. An important component of the Northwest Forest Plan was the Aquatic Conservation Strategy and its emphasis on the importance of riparian areas across this landscape. Riparian Reserves were established to: 1) protect riparian-dependent and aquatic ecosystems and 2) to provide habitat for upslope communities of fauna and flora. Interim widths of the Riparian Reserves designated in the Northwest Forest Plan are determined by "site-potential tree heights". Reserve widths are designated as either one (perennial, nonfish-bearing or intermittent streams) or two (perennial fish-bearing streams) site-potential tree heights. A site-potential tree height is the average maximum tree height that can be attained on a given site at age 200 or older.

Riparian Reserves can encompass over 80% of the coastal forests of the Pacific Northwest. Characteristics that contribute to these extensive reserves include a landscape that is highly dissected by streams, relatively short and steep topography, environmental conditions favorable for the

Figure 1.—Riparian zones are amongst the most ecologically diverse and productive components of the forested landscape in the Pacific Northwest. Diverse riparian vegetation and large woody debris contribute to the habitat and complex functions provided by this coastal Oregon stream.

growth of large and tall tree species and diverse species composition. The Aquatic Conservation Strategy of the Northwest Forest Plan stressed that management activities in Riparian Reserves maintain or improve current riparian habitat conditions, functions, and processes. A watershed analysis process established under the Northwest Forest Plan and variations employed by state agencies and private timber companies are now used for assessing the state of current conditions, the historic conditions, identifying issues and knowledge gaps, and developing management options in riparian areas.

WATERSHED ANALYSIS

A planning process known as watershed analysis is conducted on watersheds to determine current condition of the biotic, abiotic, and social elements within the watersheds (EPA and others, 1995). The watershed analysis process is an important collaboration between land managers, researchers, and private landowners. Analysis of historical conditions and the frequency and impact of natural and human caused disturbances help to establish reference conditions for a watershed. Landscape conditions that influence the function and ability of the watershed to provide the ecosystem values and meet the health and productivity goals are identified. Perhaps most important in the watershed analysis process is determining what is known and unknown about the functions and processes at work. This helps to identify data gaps and define research needs. A listing of the management opportunities that assist in changing the watershed toward a desired future condition is often included at the conclusion of the watershed analysis.

The information from watershed analysis can be used to validate or modify riparian reserve boundaries (widths). Following watershed analysis, management practices on federal lands are designed and implemented to attain the goals of the Northwest Forest Plan's Aquatic Conservation Strategy. These Practices often include silvicultural and instream treatments to enhance terrestrial and aquatic habitat. The outcomes of these practices are monitored for efficacy through an adaptive management learning process.

Land managers need to understand the processes at work within riparian areas and the interrelationship to aquatic and terrestrial species and functions (Figure 1). An understanding of riparian areas begins with an awareness of the geomorphology of the landscape, hence the type and longevity of material within the stream, and mechanisms at work for distributing woody debris, rock, cobble, and sediment throughout the course of the stream. Classifying the width and gradient of the stream reaches assists in identifying various processes at work within the system.

With this information, managers can then determine if the current vegetative composition is appropriate, within the

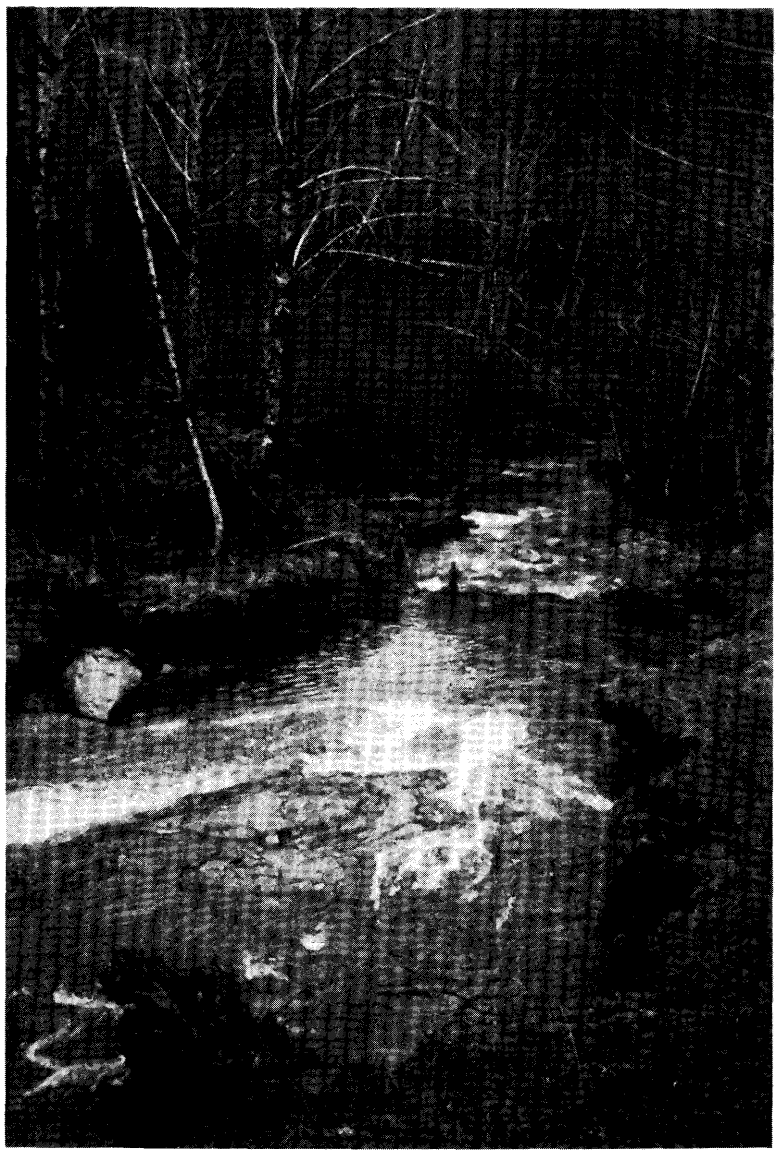

Figure 2.—Past management practices adjacent and within this coastal Oregon stream has contributed to bank erosion, scouring to bedrock, lack of large woody debris, and the dominance of red alder and salmonberry.

context of the entire stream system being considered. Silviculture is often the most appropriate long-term and cost-effective method for enhancing or restoring healthy conditions in riparian areas (Newton et al. 1996). With specific objectives clearly defined, the silviculturist can develop prescriptions that can shift the current riparian forest to a desired future condition.

Silvicultural practices can help grow large conifers within riparian areas that provide shade and wood to streams over long periods of time. Large conifers in the stream (standing or down) are important structural components. When standing, large conifers provide habitat to a wide variety of birds, mammals, insects, and invertebrates. When fallen, large conifers in riparian areas continue to provide habitat to terrestrial wildlife species and often benefit aquatic species as well (Maser and Sedell 1994).

THE HARDWOOD- AND SHRUB-DOMINATED RIPARIAN LANDSCAPE

Previous land-use and harvesting practices have produced a fragmented landscape with isolated patches of older coniferous forests and extensive areas of hardwood-dominated stream reaches. Historic clearing for homesteads, logging, and changes in fire patterns have altered the nature of streamside vegetation. In pre-settlement coastal forests, riparian vegetation often consisted of a mix of deciduous tress such as bigleaf maple (*Acre macrophyllum*) and red alder (*Alnus rubra*) with conifers such as western redcedar (*Thuja plicata*), Douglas-fir (*Pseudotsuga menziessii*), Sitka spruce (*Picea sichensis*), grand fir (*Abies grandis*), or western hemlock (*Tsuga heterophylla*). Due to human influences, many streams (Figure 2) have been degraded and an overstory of red alder and an understory of salmonberry (*Rubus spectabilis*) now heavily dominates these riparian areas.

Riparian areas in the coastal mountains of the Pacific Northwest are physically complex. Microsite variations in soil, drainage, light, geomorphology, and edge occur within short distances. The variations in riparian microsites result in a range of plant growing conditions capable of supporting diverse plant communities. The dense canopies associated with red alder and shrub-dominated riparian areas often mask these complex site characteristics. Large woody debris on the forest floor is often sparse or absent in hardwood- and shrub-dominated riparian areas in the coastal mountains of the Pacific Northwest.

Forest managers, especially fisheries biologists are concerned about the state of vegetation and habitat in these riparian areas. Natural regeneration of both conifer and hardwood trees in red alder- and shrub-dominated riparian areas are extremely sparse (Minore and Weatherly 1994; Hibbs and Giordano 1997). Establishing conifers in these hardwood- and shrub-dominated areas is desirable both for fish and wildlife habitat and for future sources of timber and special forest products. However, restoring or converting these areas to conifer-dominated or mixed stands is often unsuccessful under the heavy shade of red alder. Competition from salmonberry and damage from beaver and animal browsing add to the difficulty. Salmonberry is an extremely aggressive and persistent shrub that occupies highly productive riparian and upslope sites in the Coast Ranges of the Pacific Northwest. The ability of salmonberry to reproduce effectively from rhizomes, seeds, and layering allow it to persist, grow, and invade sites following disturbance (Tappeiner et al. 1991). The multiple mechanisms for salmonberry reproduction often allow it to

rapidly occupy sites and effectively exclude tree regeneration.

Red alder is a fast growing, nitrogen-fixing, relatively short-lived, shade-intolerant deciduous tree mainly found on moist, well-drained sites (Harrington et al. 1994, Harrington 1996). At maturity red alder is small in diameter and produces much less wood volume when compared to most conifers (Hibbs 1996). Alder logs decay rapidly and often cannot provide the long-term function of providing large woody debris input into the stream. Large, long lasting logs are an important component of stream channels in the Pacific Northwest (Maser and Sedell 1994). They help create pools and substrate habitat for fish and other aquatic-dependent vertebrates and invertebrates (Bilby and Ward 1991). Many salmon restoration projects have focused on installing logs in stream channels to improve habitat for fish in streams. While this may be a successful short-term solution, these restoration efforts are costly and not self-sustaining. Managing riparian areas for recruitment of large trees from riparian and upslope areas provide a long term and sustainable option for developing and maintaining productive stream and riparian habitat.

A STUDY ON GROWING CONDITIONS, STAND DYNAMICS, AND TREE REGENERATION IN HARDWOOD- AND SHRUB-DOMINATED RIPARIAN AREAS

Opportunities for enhancing riparian habitats desirable for fish and wildlife and tree regeneration in areas dominated by red alder may be forfeited if riparian buffers are not actively managed. Red alder and salmonberry form plant communities that are biologically quite stable and resilient. Understory shrub cover often increases with overstory age. These plant communities create conditions that often exclude tree regeneration, crucial for producing future sources of large wood for fish, wildlife, and timber (Hibbs and Giordano 1996; Nirenburg 1996).

Numerous factors can affect tree regeneration in the Oregon Coast Range. Light availability; soil moisture, rooting substrate; seed source availability; disturbance type, intensity, timing, and frequency; and animals are some the factors that affect tree regeneration. We have found that one of the key elements limiting tree regeneration in the Oregon Coast Range is light (Chan 1990). Light levels under the shade of a red alder canopy are very low. Alder also responds quickly to thinning or gap creation through epicormic and main canopy branch growth. Salmonberry and other associated understory shrubs also compete with tree seedlings for light and water. Competitions from either or both red alder and understory shrubs are major limiting factors for tree regeneration in the Oregon Coast Range.

Scientists and managers of different disciplines from the USDA Forest Service, USDI Bureau of Land Management, Oregon State University , Oregon State Department of Forestry, forest industry, and counties in partnership through the Coastal Oregon Productivity Enhancement Program (COPE) have established studies on the ecology and silviculture of riparian areas in coastal mountains of Oregon. The objectives from one of the studies is to examine: 1) the environmental causes for the scarcity of tree regeneration, and 2) a variety of silvicultural approaches for tree regeneration in hardwood- and shrub-dominated riparian areas. The study focuses on the effects of riparian growing conditions (e.g., light and soil moisture levels and understory shrub and overstory hardwood density and dynamics) on the regeneration of six tree species (Douglas-fir, western redcedar, Sitka spruce, western hemlock, grand fir, and red alder) in the Oregon Coast Range.

Results from the study indicate that growth of the underplanted trees (except red alder and Douglas-fir) in partially thinned riparian alder stands (40-60% of full light penetrating through the canopy) are similar to trees growing in large openings where the canopy was completely removed. However, rapid regrowth of the thinned alder canopy at 8-12% annually may again lead to closed canopy and light-limiting conditions.

Light levels are often low (less than 10% of open conditions) in alder- and shrub- dominated riparian areas (Figure 3a). Light availability is highly correlated with tree regeneration in riparian areas. Light levels above 10-20% of open conditions are necessary for moderate (>60%) long-term survival of six commonly planted conifers and hardwoods. Canopy openings where between 30-70% of full sunlight penetrates are necessary for promoting good tree growth. Between 50-90% of the alder trees in a stand (depending on size, age, and vigor) may have to be thinned to achieve canopy openings of 30-70% (Figure 3b).

Thinning the overstory also favors understory shrub and herb development (Figure 3c). Repeated annual cutting of the understory during the active growing season is effective in preventing the increase in cover and height of most shrubs, and is most effective under a partially or unthinned overstory. Tree regeneration for each of the six tested tree species was enhanced when the understory vegetation was cut at least once a year. However, cutting the understory vegetation more than once a year did not increase the survival and growth of tree regeneration over a single annual cutting. Cutting the understory twice a year shifted the understory composition from a shrub-dominated plant community to an herb- and grass-dominated community. Left undisturbed, the understory shrubs and herbs can have a strong competitive effect on tree regeneration.

Riparian areas are variable: a range of silvicultural treatment options, including choice of planted species can be applied to reach specific goals for fish and amphibian habitat, timber, clean water, and special forest products. Active riparian vegetation management in hardwood- and shrub-dominated riparian areas is often necessary to create growing conditions (i.e., increased light) that favor tree

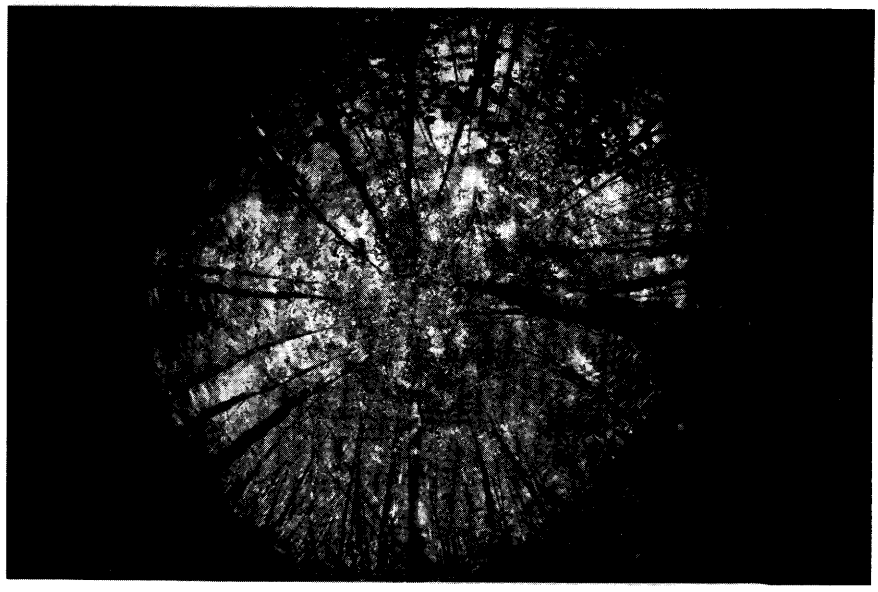

Figure 3a.—Dense plant canopies in riparian areas dominated by red alder and salmonberry effectively exclude tree regeneration. Light levels in this stand are approximately 3 percent of open conditions.

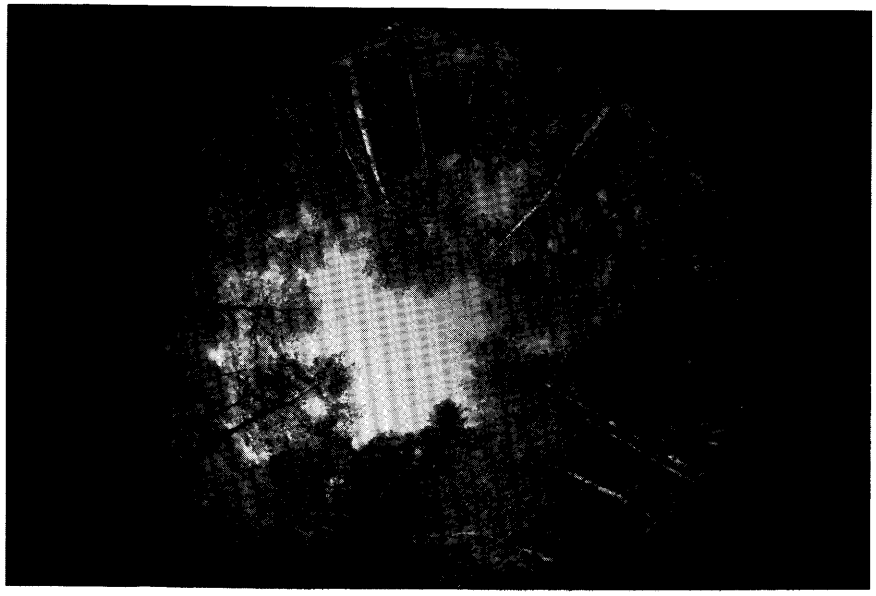

Figure 3b.—A substantial portion of the overstory canopy of red alder must be thinned to create conditions favorable for tree regeneration in riparian areas. The canopy of this thinned 46 year old red alder stand has closed almost 50% five years after thinning.

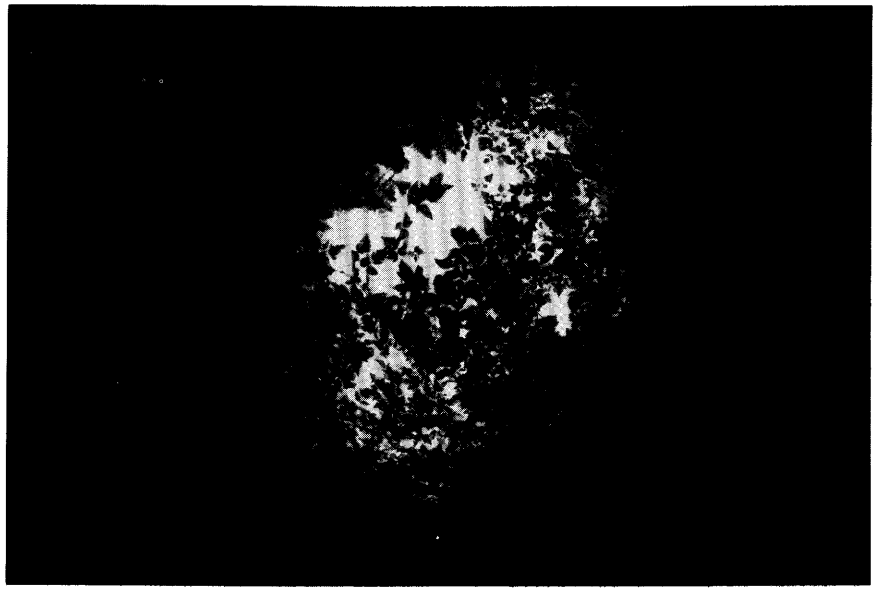

Figure 3c.—Understory shrubs such as salmonberry can quickly fill gaps created in the overstory and exclude tree regeneration.

Figure. 4.—Successful tree regeneration can occur in hardwood and shrub dominated riparian areas of the Oregon Coast Range through active management of riparian vegetation.

regeneration and understory development (Figure 4). Managers should focus on treatments that create adequate tree growing conditions (e.g., light availability) for a particular site versus targeting for a blanket prescription to fit all riparian areas.

Adequate tree regeneration and understory development can serve as the basic structural units for building, sustaining, and optimizing the composition and function of riparian plant communities. Short-term disturbances that promote tree regeneration in previously degraded riparian sites currently dominated by hardwoods and shrubs, are likely necessary to achieve long-term goals for restoring riparian processes and functions.

Emphasis on technology transfer by both researchers and managers through workshops, field trips, publications, and consultations have accelerated adoption of new knowledge and improved techniques for larger scale riparian projects. Ongoing visits and evaluations of the research and demonstration sites by managers, researchers, interested publics, and policy makers have further enhanced the value of this partnership between research and management.

CONCLUSIONS

The application of active management in riparian areas to promote tree regeneration for habitat complexity on a landscape basis should be based on a program of learning through adaptive management (Hayes et al. 1996). We have learned much about silviculture in riparian areas (especially tree regeneration) since our partnership began seven years ago. We realize that there is more to learn, since successful regeneration of trees in riparian areas merely establishes part of the foundation from which managers can build riparian stands and landscapes. We have little information on what is, and how to achieve, the optimal range of riparian disturbances and stand composition and structures. We also lack knowledge on appropriate mixes and distributions of hardwoods and conifers in a watershed. Historical conditions can provide some clues, but do not provide actual evidence of proper function. We continue to learn about how different silvicultural approaches drive stand dynamics and structure, species interactions, and succession in riparian areas. The long-term role and consequences of establishing extensive riparian buffers and their management will also need to be examined. The effects and interactions of riparian silviculture on animal populations remain largely unknown. The role of animals such as beavers on tree regeneration and stand dynamics will need to need to be closely monitored.

The role of silviculture in the active management of riparian areas will continue to gain importance as a long-term solution for enhancing and restoring degraded riparian areas. The effectiveness of silvicultural options in riparian areas will depend on continuing and building the partnership between researchers and managers. Active involvement of specialists (e.g., fisheries and wildlife biologists, botanists, soil scientists, engineers, hydrologists, scientists) in defining objectives and issues with silviculturists is critical.

Elements for Successful Partnerships between Research and Management: a Commentary

The complexity of land management issues has increased, but resources available for addressing these issues have

actually decreased for most public agencies. Partnerships between land managers and researchers can be an efficient mechanism for leveraging resources and expertise to focus on important issues. A successful partnership between researchers and resource managers focuses on common issues, problems, and goals. Successful partnerships are especially valuable in studies that are designed for long-term value.

Researchers may propose activities that may be at odds with current best management practices (e.g., cutting all the trees along a section of a stream). Likewise, managers realize that some of our current assumptions might have to be challenged to gain insight on their effectiveness. Thus, a successful partnership may require that managers and researchers assume both traditional and non-traditional approaches.

The traditional roles of land managers in research projects are to: 1) identify issues and problems, 2) work with researchers and stakeholders to implement projects, and 3) alert researchers to potential problems that may affect implementation. Questions that managers might ask researchers include: Is the study pertinent to my needs? What solutions or new knowledge will the study provide? Will the study be well utilized? Is the study visible and supported by stakeholders? A researcher's traditional role is to conduct good science that leads towards a solution or better information. The researcher: 1) develops a problem analysis, 2) packages issues into testable hypotheses, 3) develops an appropriate experimental design, and 4) designs realistic studies that consider site constraints, management concerns, and limitations of resources.

A successful partnership between managers and researchers often dictates procedures that go beyond traditional experimental protocol. A common issue cited by managers is that researchers are often not familiar with the operational details of: 1) environmental laws such as the National Environmental Protection Act and Threatened and Endangered Species Act and the associated consultation and public comment process, 2) project scheduling (it might take two or more years to fully implement a field study), 3) the requirements of the Northwest Forest Plan including watershed analyses, and permitted practices under different land-use designations. Researchers also need to be aware of the manager's funding process and concerns about public perceptions. Researchers can address the needs of land managers by facilitating district and forest involvement in the study. Managers should be provided with progress updates and findings in a timely manner. Researchers should work with managers to interpret and extend research results into operational activities.

Managers must understand a study before they can fully appreciate its value. Understanding a study will often require that managers be aware of the factors that lead to good research such as problem analysis, hypotheses testing, and methods. Managers should work with the researchers in fine-tuning the design and implementation of the study. Managers should be aware of the study design and methods including: the treatments applied, concepts of replication, procedures that may lead to bias, and consistency in which procedures are applied. Managers will likely encounter some procedures in a study that might be contrary to or in addition to what would be done at an operational level. Hopefully, managers will perceive the studies as providing important information leading towards adaptive management. Finally, managers and researchers need to realize the limitations of current and new knowledge and use the information with good common sense. Our partnership has demonstrated an important role for silviculture in the active management of riparian vegetation in the Oregon Coast Range.

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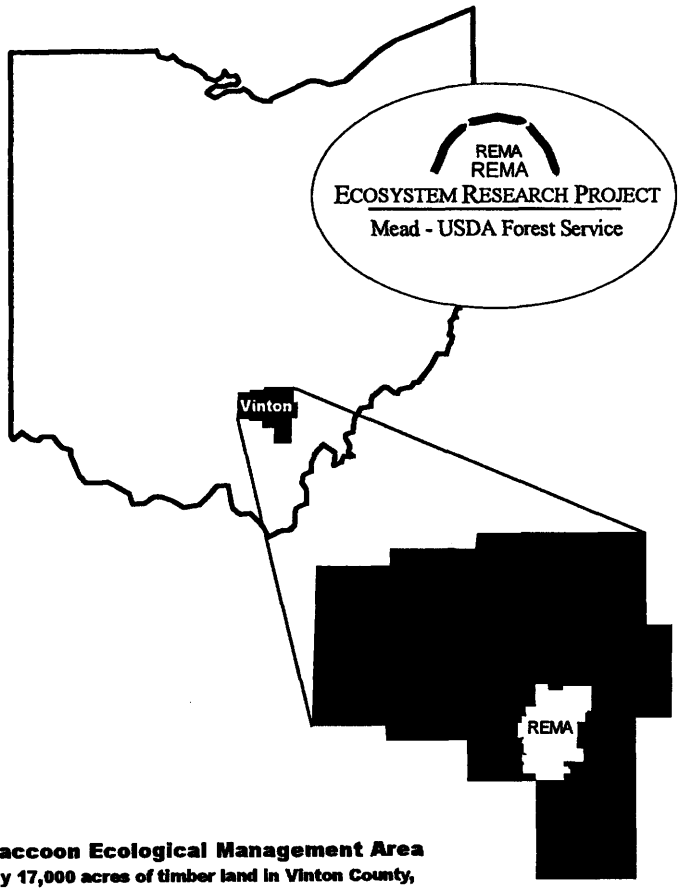
Raccoon Ecological Management Area: Partnership between Forest Service Research and Mead Corporation

Daniel A. Yaussy, Wayne Lashbrook, and Walt Smith[1]

Abstract.—The Chief of the Forest Service and the Chief Executive Officer of Mead Corporation signed a Memorandum of Understating (MOU) that created the Raccoon Ecological Management Area (REMA). This MOU designated nearly 17,000 acres as a special area to be co-managed by Mead and the Forest Service. The REMA is a working forest that continues to produce timber and pulpwood for Mead. Current Forest Service research within the REMA consists of two sites of a large, oak ecosystem restoration research project, and one site of a long-term oak stand density study. Facilities provide a place for researchers to stay while collecting data, and classrooms for the educational workshops presented for the public. The REMA will provide new sites for silvicultural and other demonstrations.

INTRODUCTION

On June 29, 1995, a Memorandum of Understanding (MOU) was signed that created the Raccoon Ecological Management Area (REMA) in southeastern Ohio (Fig. 1). This MOU was signed in the U.S. Congressional Office building by Jack Ward Thomas, then Chief of the Forest Service, and Steven C. Mason, Chairman of the Board and Chief Executive Officer of Mead Corporation.



The Raccoon Ecological Management Area
Nearly 17,000 acres of timber land in Vinton County, Ohio, is the site of an extensive Mead Corporation-USDA Forest Service ecosystem reasearch project designed to learn more about forest-related matters such as vegetation, wildlife, soils, landscape ecology, forest health, aesthetics, and other issues affected by forest management practices.

Figure 1.—Location of the Raccoon Ecological Management Area that is jointly managed by the Mead Corporation and the USDA Forest Service.

Mead has operations in 30 countries around the world and is recognized as a leading producer and supplier of paper and paperboard products. Mead has designated their Woodlands Division in Chillicothe, Ohio, as their liaison in this endeavor.

The Forest Service representative for this MOU is the Forest Ecosystem Modeling project located in Delaware, Ohio. The full project title is: Quantitative Methods for Modeling Response of Northeastern Forest Ecosystems to Management and Environmental Stresses. The scientists are involved with studies funded by the Forest Service's Global Change program and Ecosystem Management research grants.

The Forest Service and Mead will cooperatively manage the nearly 17,000 acres of contiguous mixed-oak forest designated as the REMA. The REMA was created to develop and test various forest ecosystem management practices at the stand and landscape scale. This is a working forest rather than an experimental forest and Mead retains all rights to manage the tract as needed. The cooperators are developing a management plan for the area that will identify near-term and long-term opportunities for research.

HISTORY

The REMA is the largest area of contiguous forest in Ohio under private ownership. It is located in the Hanging Rock region, which was a large producer of iron ore before and during the Civil War. The area had two iron furnaces that operated between 1850 and 1890 (Hutchinson[2]). The

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[2]Hutchinson, Todd. In preparation. History of the mixed oak forests and land-use in Southern Ohio.

surrounding hillsides were cleared, repeatedly, to produce charcoal used to smelt the iron ore. After the furnaces closed, the land reverted to forest with some limited farming and grazing activities. There is evidence that low intensity wildfires burned through the area every 2 to 3 years (Sutherland 1997). Disturbance history (clear cutting, ample stump sprouts, frequent fires, and possible grazing) determined the species composition of the resulting forest. The overstory of the existing forest is 100 to 150 years old, consisting mostly of white, chestnut, scarlet, and black oak (*Quercus alba, Q. prinus, Q. coccinea, Q. velutina*). In 1952, Baker Wood Preserving Company bought land in Vinton County, Ohio, and set 1,200 acres aside for use by the Forest Service as the Vinton Furnace Experimental Forest (VFEF). A decade later, Mead purchased the tract and maintained the relationship with the Forest Service.

Many of the studies and demonstrations on the VFEF date from the mid to late fifties and include the comparison of different cutting practices on timber production and species composition, the effect of the size of canopy opening on composition of regeneration, conversion of dry sites to pine, and the effect of understory removal on the growth of the overstory. Like many of the experimental forests in the East, we claim that Ben Roach, a well-known research silviculturalist, performed much of his research on complete clearcutting and stand density on our forest.

FACILITIES AND EDUCATION

The headquarters area of the VFEF consists of an equipment shed, fuel shed, an office and lodging for overnight stays, and an education/workshop building. In 1996, Mead and the Forest Service conducted 33 tours and training exercises on the VFEF and REMA involving 812 people. Many of the tours are presented by Mead to wholesale purchasers of their products. These "Paper Knowledge Tours" start in Mead's Chillicothe paper mill and end at the VFEF with visits to some of the demonstration areas. We also have provided tours for college classes from The Ohio State University, Hocking College, and the University of Kentucky. Last year we even had a group from Sweden. Other tours have been given to the local Sierra Club, state legislators, and the Farm Bureau.

Hocking College and Mead also use the facilities to conduct courses in Best Management Practices, Clear Water, Chainsaw Safety, Logger Training, and Sustainable Forestry. The VFEF was also a site for the Society of American Foresters Central States Forest Soils Workshop in 1995.

With the intense use of the area for tours, workshops, and education, Mead is planning to replace the vintage World War II Quonset hut used as a classroom, with a new training/ workshop building.

CURRENT RESEARCH

Current research on the REMA includes a study on the effects different thinning levels have on residual trees, development of a computer based ecosystem classification system, a study of the effects of prescribed burning on the ecosystem, and a case study to regenerate shortleaf pine under a shelterwood system. The thinning-level study was installed in 1959 as one of two sites on Mead land in Ohio. Two other replications were located on the Daniel Boone National Forest in Kentucky. The original goal of this study was to develop recommended levels of thinning for management of even-aged upland oak stands. The information has been incorporated into the GROAK and OAKSIM growth and yield simulators. Although most of the information on the effects of thinning have been reported, we are continuing to remeasure the plots every 5 years. We are currently using the control plots for a drought/mortality study to determine which soil and climatic factors are related to differential mortality of species.

In 1993, Mead planned to harvest a mixed shortleaf pine-oak stand and allow it to regenerate to hardwoods. When Forest Service scientists were asked if they had any suggestions, the idea of a shortleaf shelterwood cut was proposed. So far the results have not been favorable. Our plans are to conduct a prescribed burn through part of the site to improve conditions for seeding.

Using the information available from a Geographical Information System (GIS), Iverson and others (1996) developed an integrated moisture index for the REMA. The index uses information from the county soil survey and a digitized topography map to compute the influence of slope, aspect, water flow, curvature, and water-holding capacity on the amount of moisture available to the trees. This computer generated index can predict species composition and site index. It is now used as a variable in any study being planned by our project.

The largest field study in which our partnership is involved is the "Effectiveness of prescribed burning in the ecological restoration of mixed-oak forest ecosystems in southern Ohio". Two study areas (250 acres each) are located on the REMA, with an additional two areas on the Ironton District of the Wayne National Forest. The premise of this study is that prescribed burning will remove much of the understory competition to oak seedlings (red maple (*Acer rubrum*), sugar maple (*A. saccharum*), dogwood (*Cornus florida*), and blackgum (*Nyssa sylvatica*) saplings) and allow them to advance to the sapling stage, thereby providing advanced reproduction to replace overstory oaks lost to mortality or harvesting. Various aspects of the ecosystem are being studied by many partners. Scientists from The Ohio State University are studying the effects of prescribed burning on neo-tropical migratory birds, soil microbiology and nutrients, and insects. The Ohio Department of Natural Resources, Division of Natural Areas and Preserves is cooperating with The Nature Conservancy in studying the effects of the fires on herbaceous plants. Ohio University is investigating the effect of burning on the amount of light reaching the forest floor. Forest Service scientists are monitoring the species composition, mortality, and quality changes of the woody species.

With the efforts of so many scientists concentrated on these areas, interesting offshoot studies have emerged concerning

threatened and endangered (T&E) species. One of the largest populations of timber rattle snakes, on Ohio's T&E list, has been located and tracked. Individual snakes have been captured and implanted with radio transmitters so that their movements could be followed throughout the year. The larger males can roam up to 5 miles before returning to the den.

A former candidate for the federal T&E species list is Bentley's bent reed grass *(Calamagrostis porteri var. insperata).* This species has been found in large patches on both of the study areas of the REMA, but is found in only a few locations in Missouri, Arkansas, and Illinois (Schneider 1995). Potentially the largest populations in the world are on the REMA. This plant rarely flowers and viable seeds have never been found.

CURRENT MANAGEMENT

As a member of the American Forest and Paper Association (AF&PA), Mead subscribes to the principles of the Sustainable Forestry Initiative (SFI). These principles focus on 1) sustainable forestry, 2) responsible economic and environmental practices, 3) forest health and productivity, 4) protection of sites with special significance, and 5) continuous improvement of forestry practices. During the past 2 years, some 2 dozen companies have resigned their membership from AF&PA, and another 15 companies have been suspended from membership for failure to confirm their participation in the SFI. Even with the loss of these companies from the program, the 150 association members own or control 52.7 million acres of the 70 million acres of industrial forest land in the nation.

Currently, Mead is in the process of removing veneer-quality stems from the REMA tract and plans to complete this by the year 2000. This management is in response to two different pressures: forest age and gypsy moth. In the 100- to 150-year old forest, many of the scarlet and black oaks have died or are dying and the older stems are being recovered before the value is lost. The other major threat is the gypsy moth (*Lymantria dispar*) which should have an impact within the next 5 to 10 years. The gypsy moths' preferred food is oak leaves which jeopardizes the REMA. Removal of oaks from the overstory is one of the silvicultural methods of reducing the risk of mortality due to gypsy moth (Gottschalk 1993). These removals are being conducted with an advanced forwarder designed to reduce the impacts on the soils and are not occurring on sites where there is current or planned research.

Mead does not own the mineral rights under some of the REMA surface. Strip mining for coal is occurring in the southwestern corner of the tract and there are threats to the northern portion. In areas in which stripping is imminent, Mead is recovering all the wood resource possible. These areas do not lend themselves to the establishment of long-term forest management research.

FUTURE RESEARCH

Mead and the Forest Service are in the planning stages of implementing a landscape-scale inventory and monitoring scheme, which is needed to develop a long-term management plan for the REMA. This will involve the use of permanent plots with collection of data from ecosystem components other than just the timber resource. These methods, when developed, could be used in National Forest Systems (NFS) landscapes as well as those of industrial forest lands to provide estimates for any portion of the area.

Areas are being located for an extension of the prescribed burning study. In the new areas, we will use herbicides to remove larger poles and saplings as recommended by Loftis (1990). With the exclusion of fire in the recent past, many stems of maple, dogwood, blackgum, and other shade tolerant species, have grown into the understory of the oak dominated overstory. This understory can contain up to 30 percent of the stocking in a stand. We are proposing to remove this shade tolerant understory with the injection of herbicides. Prescribed burning will be used on half of the sites to promote the establishment of oak seedlings and sprouts. This study will be installed on relatively moist sites, where advanced regeneration of oak seedlings and saplings is seldom present.

With Mead's commitment to the Sustainable Forest Initiative, they are quite interested in evaluating the effects of short rotations on the productivity of the soils. With the deposition of atmospheric nitrogen reducing the amount of calcium available to the trees, they are looking for strategies to mitigate the effect with the use of mill sludge and stack ash.

CONCLUSION

The creation of the REMA and the partnership between the Forest Service and Mead are beneficial to both entities and the communities within Ohio. The long-term and cutting-edge research in the area involves and benefits Forest Service scientists, Mead, the NFS, universities and state agencies. The educational programs and tours improve logging and forestry practices within Ohio and inform the public what forestry is and what it can be.

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