USDA United States Department of Agriculture

Forest Service

Northeastern Forest Experiment Station

General Technical Report NE-238

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.

Manuscript received for publication June 1997

Published by:

USDA FOREST SERVICE
5 RADNOR CORP CTR SUITE 200
RADNOR PA 19087-4585

October 1997

For additional copies:

USDA Forest Service
Publications Distribution
359 Main Road
Delaware, OH 43015
Fax: (614)368-0152

Visit our homepage at **http://www.nena.org/NE_Home**

Communicating the Role of Silviculture in Managing the National Forests

Proceedings of the National Silviculture Workshop

May 19-22, 1997

Warren, Pennsylvania

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
Forest Management
Washington, DC

Nelson Loftus
Forest Management Research
Washington, DC

Contents

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

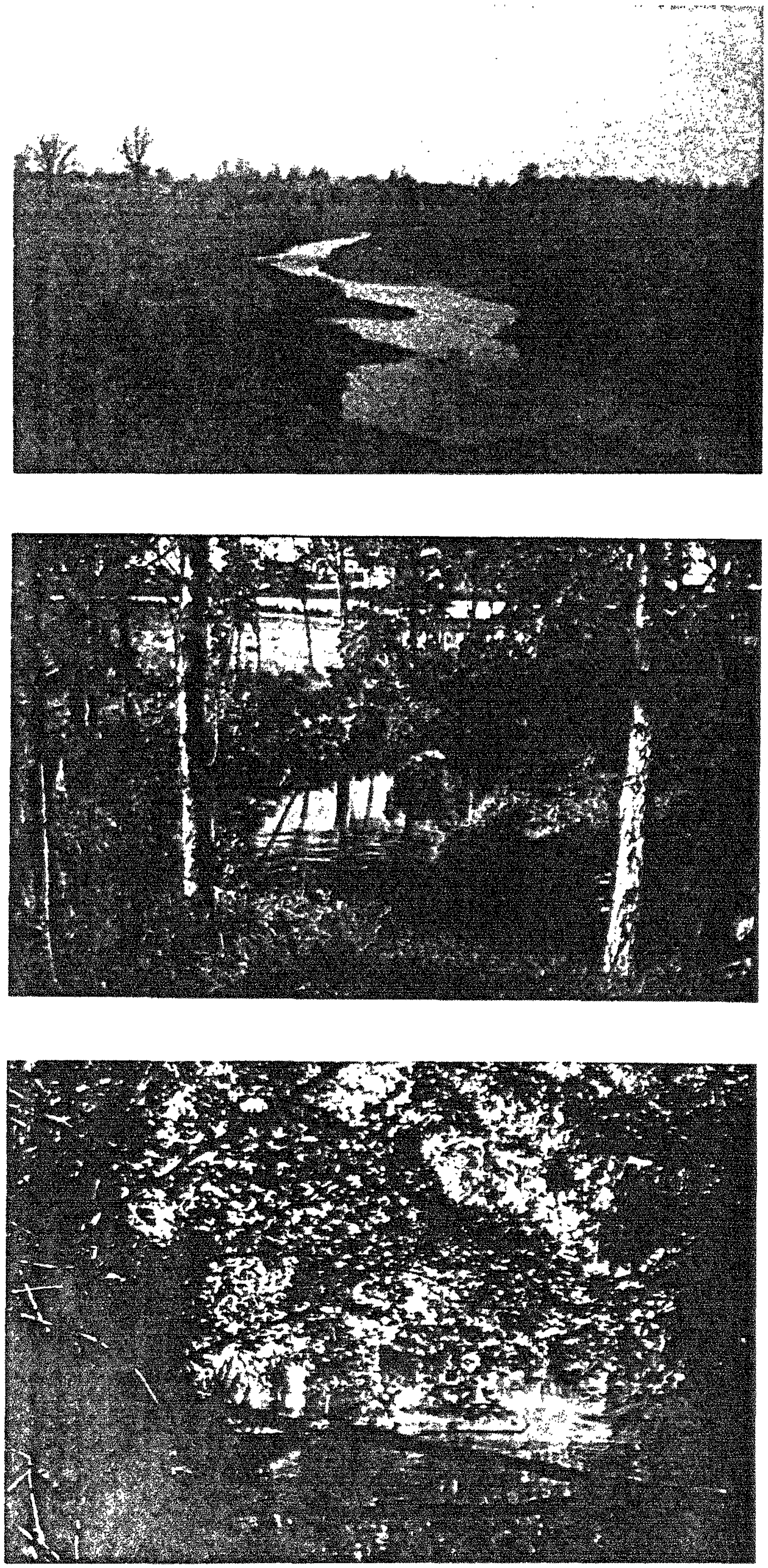
We're faced with the charge of reversing the prevailing notion that silviculturists "just want to cut trees," that our interests are limited to the production of timber crops and to detecting the culmination of mean annual increment. Some have stepped forward. Gustafson and Crow (1996) show how silvicultural 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

B

C

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.

ACKNOWLEDGEMENTS

Many of the views we have expressed trace to discussions with colleagues like you. We particularly acknowledge Tom Atzet, Jim Barnett, Tom Crow, Dean DeBell, Ken Denton, John Fiske, Dick Fitzgerald, Mel Greenup, Doug Leisz, Nelson Loftus, Gary Nakamura, Ron Stewart, John Tappeiner, Bruce Van Zee, and John Zasada for their insights and suggestions.

LITERATURE CITED

Baker, F. S. 1946. **The place of silvics in the development of American silviculture.** Journal of Forestry 44: 964-967.

Baker, F. S. 1950. **Principles of silviculture.** McGraw-Hill Book Company, Inc., New York.

Bergoffen, W. W. 1949. **Questions and answers.** In: Trees. The yearbook of agriculture. U.S. Department of Agriculture, Washington, D.C. p. 19-36.

Bolle, A. W. 1970. **A select committee of the University of Montana presents its report on the Bitterroot National Forest.** University of Montana. Missoula, MT. 33 p.

Cunningham, W. P.; Saigo, B. W., 1997. **Environmental science.** 4th ed. W. C. Brown, Publishers. Dubuque, IA.

Daniel, T. W.; Helms, J. A.; Baker, F. S. 1979. **The practice of silviculture.** 2nd ed. McGraw-Hill Book Company. New York.

Devall, B. (editor). 1993. **Clearcut: the tragedy of industrial forestry.** Sierra Club Books and Earth Island Press. San Francisco, CA.

Drengson, A. R.; Taylor, D. M. (editors). 1997. **Ecoforestry. The art and science of sustainable forest use.** New Society Publishers. Gabriola Island, B.C.

Finnish Forest Association. 1997. **The birth of silviculture.** Internet Access: http://www.metla.fi/forestfin/intro/eng/0.4.htm. 5 p.

Ford-Robertson, F. C. (editor). 1971. **Terminology of forest science, technology practice and products.** English language version. The Multilingual Forestry Terminology Series No. 1. Society of American Foresters. Washington, DC.

Gustafson, E. J.; Crow, T. R. 1996. **Simulating the effects of alternative forest management strategies on landscape structure.** Journal of Environmental Management 46: 77-94.

Haeckel, E. 1866. **Generelle morphologie der organismen.** 2 volumes. Reimer, Berlin.

Hawley, R. C. 1946. **The practice of silviculture.** 5th ed. John Wiley & Sons. New York.

Hermann, R. K. 1976. **Man and forests—a prodigal relation.** In: Forests and future resource conflicts. Northwest Area Foundation Series, School of Forestry, Oregon State University, Corvallis: 29-51.

Janzen, H. H. 1996. **Is the scientific paper obsolete?** Canadian Journal of Soil Science 76: 447-451.

Knudson, T. 1991. **Majesty and tragedy: The Sierra in peril.** 1991. The Sacramento Bee, Metro Final Section. Page A1. McClatchy Newspapers, Sacramento, CA.

Maser, C. 1988. **The redesigned forest.** R. & E. Miles. San Pedro, CA.

Moore, J. A. 1994. **We need a revolution—teaching biology for the twenty-first century.** Bioscience 43: 782-786.

Northern California Society of American Foresters. 1993. **Communication plan for Northern California Society of American Foresters 1993-1998.** Copy on file at the University of California Cooperative Extension Office, Redding, CA.

Peters, R. H. 1995. **A critique for ecology.** Cambridge University Press, New York.

Pinchot, G. 1947. **Breaking new ground.** Harcourt, Brace & Company. New York.

Reid, R. L. 1983. **A timber baron's lexicon.** Sierra Club Bulletin 68: p. 48.

Serreni, E. 1974. **Storia del paesaggio agrario Italiano.** Gius. Laterza & Figli Spa. Rome.

Smith, D. M. 1962. **The practice of silviculture.** 7th ed. John Wiley & Sons, Inc. New York.

Smith, D. M.; Larson, B. C.; Kelty, M. J.; Ashton, P. M. S. 1997. **The practice of silviculture: applied forest ecology.** John Wiley & Sons, Inc. New York.

Tkatchenko, M. E. 1930. **Origins and propagation of forestry ideas.** Journal of Forestry, 28: 595-617.

Toumey, J. W.; Korstian, C. F. 1947. **Foundations of silviculture upon an ecological basis.** John Wiley & Sons, Inc. New York.

Watson, J. D.; Crick, F. H. C. 1953. **A structure for deoxyribose nucleic acid.** Nature 171: 737-738.

Williams, P. A.: Gordon, A. M.; Garrett, H. E.; Buck, L. 1997. **Agroforestry in North America and its role in farming systems.** In: Gordon, A. M. and Newman, S. M. (editors). Temperate agroforestry systems. CAB International. Wallingfork, UK. p. 9-84.

Zinsser, W. 1994. **On writing well.** 5th ed. Harper Collins Publisher. New York.

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

Ralph D. Nyland[1]

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.

[1]Professor of Silviculture, Faculty of Forestry, SUNY College of Environmental Science and Forestry, Syracuse, NY 13210

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.

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.

LITERATURE CITED

Allen, T. F. H. and T. W. Hoekstra. 1995. **Sustainability: A matter of human values in a material setting.** In: pp. 5-10. C. Aquirre-Bravo, L. Eskew, A. B. Villa-Salas, and C. E. Gonzales-Vicente, ed. Partnerships for Sustainable Forest Ecosystem Management: Fifth Mexico-U.S. Biennial Symposium. US For. Serv. Gen. Tech. Rpt. RM-GTR-266

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.

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

[1]Acting Deputy Chief for Programs and Legislation, USDA Forest Service, Washington, D.C.

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.
>
> 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.

LITERATURE CITED

Smith, David M.; Larson, Bruce C.; Kelty, Matthew J.; and Ashton, P. Mark S. 1997. **Practice of Silviculture.** John Wiley and Sons, Inc. New York. Page 9.

Society of American Foresters. 1930. **Formulating a forest policy.** Journal of Forestry 27(5):593-594.

Thomas, Jack Ward. 1994. **Concerning "New Directions for the Forest Service."** Testimony before the Subcommittees on National Parks, Forests, and Public Lands and on Oversight and Investigations, U.S. House of Representatives. February 3, 1994.

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).

[1]Research Plant Geneticist, USDA Forest Service, Rocky Mountain Research Station, Moscow, ID.

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).

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.

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).

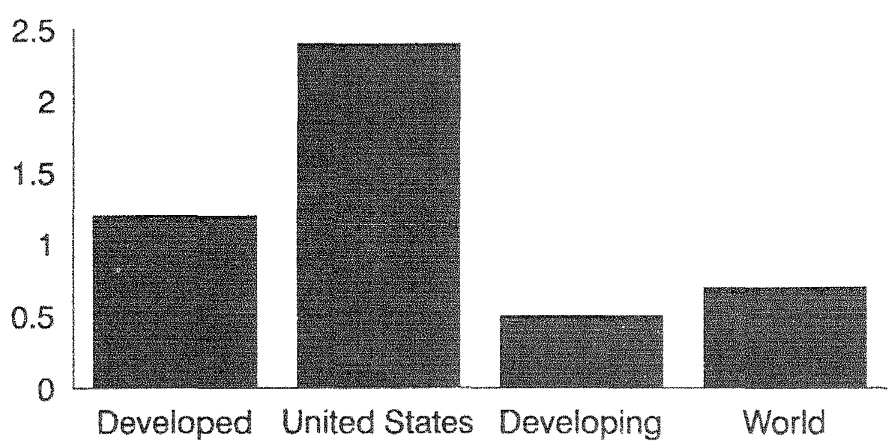


Figure 1.—Global per capita consumption of wood, in cubic meters. Each American uses 2.4 cubic meters of wood annually, which is twice the average of the developed nations and nearly 3.5 times the global average (FAO 1993).

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.

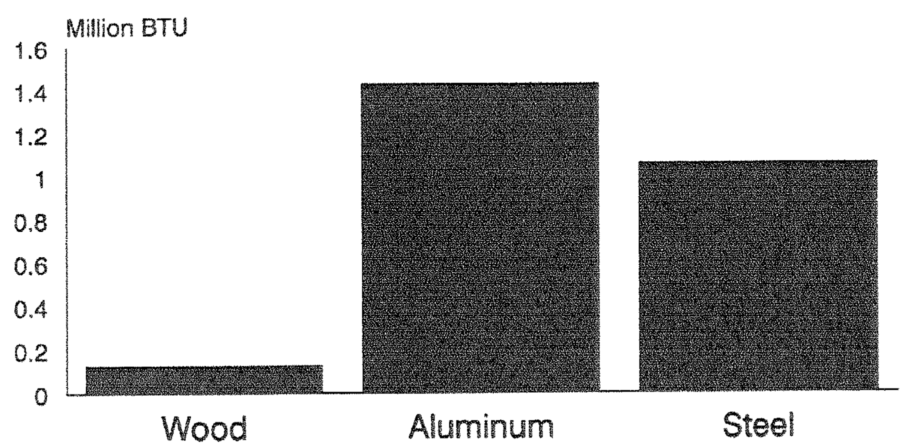


Figure 2.—Net energy consumed to extract, transport, manufacture and erect 100 square feet of interior wall using various framing materials (CORRIM 1976).

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

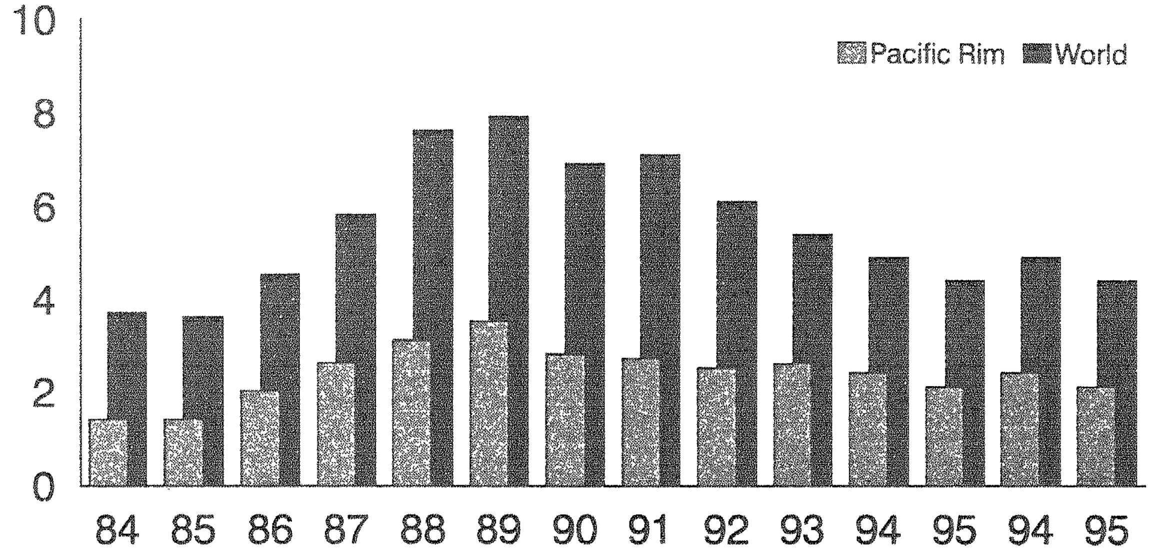


Figure 3.—Softwood lumber exports, in millions of cubic meters. Overall, volume has declined 42 percent from levels exported in the late 1980s (FAS 1996).

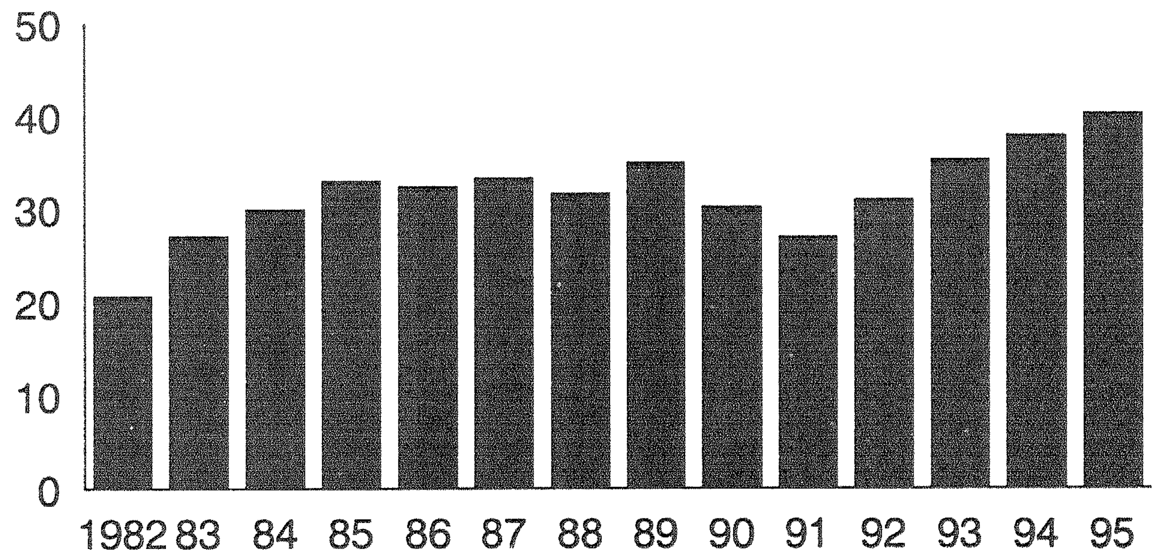


Figure 4.—Softwood lumber imports, in millions of cubic meters. Volume has increased by about 12 percent from levels imported in the late 1980s (FAS 1996).

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.

ACKNOWLEDGEMENT

Dr. William J. Libby of the Departments of Genetics and of Environmental Science, Policy and Management at UC-Berkeley (emeritus) provided many of the basic ideas in the development of this paper.

LITERATURE CITED

Backman, C. A.; Waggener, T. R. 1992. **The forest resources and export potential of the former Soviet Union.** *In:* Proceedings, Wood Product Demand and the Environment. November 13-15, 1991; Vancouver, British Columbia, Canada. Forest Products Research Society, Madison, WI. pp. 247-251.

Barbier, E. B. 1994. **The environmental effects of the forestry sector.** *In:* Organization for Economic Cooperation and Development (OECD). The environmental effects of trade. OECD, Paris.

Barbier, E. B.; Burgess, J. C.; Bishop, J.; Aylward, B. 1994. **The economics of the tropical timber trade.** Earthscan Publications, London, UK. 179 pp.

Bevis, W. W. 1995. **Borneo log: The struggle for Sarawak's forests.** University of Washington Press, Seattle. 245 pp.

Bowyer, J. L. 1992. **Alternatives to forest harvest and wood use: the environmental impacts are substantial.** *In:* Proceedings, Wood Product Demand and the Environment. November 13-15, 1991; Vancouver, British Columbia, Canada. Forest Products Research Society, Madison, WI. pp. 270-274.

Brooks, D. J. 1993. **U.S. forests in a global context.** Gen. Tech. Rep. RM-228. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO. 24 p.

Campbell, F. T.; Schlarbaum, S. E. 1994. **Fading forests: North American trees and the threat of exotic pests.** Natural Resources Defense Council, Inc. New York. 47 pp.

Committee on Renewable Resources for Industrial Materials (CORRIM) - National Research Council. 1976. **Wood for structural and architectural purposes.** Wood and Fiber 8: 1-72.

Cousteau, J. Y. 1992. **Convince to Conquer.** Address to the United Nations Conference on Environment and Development (UNCED); June 5. 1992; Rio de Janeiro, Brazil. Calypso Log August 1992: 3-6.

Daniels, J. D. 1993. **Forest Genetics & You: What's the Connection?** Forests Today & Forever 7(1): 4-5, 11.

Davis, P.; Jansen, C. 1992. **Career opportunities utilizing the urban wood fiber supply base.** *In:* Proceedings, Wood Product Demand and the Environment. November 13-15, 1991; Vancouver, British Columbia, Canada. Forest Products Research Society, Madison, WI. pp. 241-243.

Forest Ecosystem Management Assessment Team (FEMAT). 1993. **Forest ecosystem management: an ecological, economic and social assessment.** Vol. 2: 59.

Food and agriculture organization of the United Nations (FAO). 1961. **Yearbook of forest products.** FAO, Rome.

FAO. 1991. **Global harvests, food and subsistence.** 1989-2010: Wood and wood products. FAO. Rome.

FAO. 1993. **Forestry statistics today for tomorrow.** FAO, Rome.

FAO. 1994. **Pulp and paper towards 2010.** Forestry planning and statistics branch, FAO, Rome.

FAO/UNEP 1981. **Tropical forest resources assessment project**, FAO, Rome.

FAS, 1996. **Wood products trade and foreign markets: annual statistical trade issue.** Foreign Agricultural Service circular series WP 1-96, April 1996. USDA Foreign Agricultural Service, Forest Products Division, Washington, D.C.

Goheen, D. J.; Tkacz, B. M. 1993. **Pest risks associated with importing unprocessed Russian larch logs to the United States.** Western Journal of Applied Forestry 8(3): 77-80.

Government of British Columbia. 1994. **Working in partnership, British Columbia's forest renewal plan.** Queen's Printer, Victoria, B.C. 3 pp.

Graham, R. T. 1990. **Western white pine.** *In:* Burns, R. M.; Honkala, B. H.; tech. coords. Silvics of North America: 1. Conifers. Agriculture Handbook 654. U.S. Department of Agriculture, Forest Service, Washington, D.C. p. 385-394.

Haynes, R. W.; Adams, D. M.; Mills, J. R. 1993. **The 1993 RPA timber assessment update.** USDA Forest Service, Gen. Tech. Rep. RM-GTR-259. Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO. 66 pp.

Hermann, R. K.; Lavender, D. P. 1990. **Douglas-fir.** *In:* Burns, R. M.; Honkala, B. H.; tech. coords. Silvics of North America: 1. Conifers. Agriculture Handbook 654. U.S. Department of Agriculture, Forest Service, Washington, D.C. p. 527-540.

Ince, P. J.; McKeever, D. B.; Haynes, R. W. 1995. **The role of markets and technology in conservation of timber resources.** *In:* Proceedings of the 1995 International Environmental Conference. May 7-10 1995; Atlanta, GA. TAPPI PRESS, Atlanta, GA. p 315-325.

Koch, P. 1992. **Wood versus nonwood materials in U.S. residential construction: some energy-related global implications.** Forest Products Journal 42(5): 31-42.

Libby, W. J. 1994a. **Mitigating some consequences of giant sequoia management.** *In:* Aune, P., ed. Proceedings of the symposium on giant sequoias: their place in the ecosystem and society. June 23-25, 1992; Visalia, CA. General Technical Report PSW-GTR-151. USDA Forest Service, Pacific Southwest Research Station, Albany, CA. p. 142-148.

Libby, W. J. 1994b. **The role of production forestry in preventing tropical species extinctions.** *In*: Nimbyism, genetic improvement and plantation forestry: growing wood for the 21st century. March 10, 1994; Post Falls, ID. Inland Empire Tree Improvement Cooperative, University of Idaho, Moscow, ID.

Lippke, B. R. 1992. **Meeting the need for environmental protection while satisfying the global demand for wood and other raw materials: a North American and global trade perspective.** *In:* Proceedings, Wood Product Demand and the Environment. November 13-15, 1991; Vancouver, British Columbia, Canada. Forest Products Research Society. Madison, WI. p. 137-142.

Monserud, R. A.; Tchebakova, N. M.; Leemans, R. 1993. **Global vegetation change predicted by the modified Budyko model.** Climate Change 25: 59-83.

North Carolina State University (NCSU). 1996. **North Carolina State University -industry cooperative tree improvement program, annual report.** Department of Forestry, College of Forest Resources, North Carolina State University, Raleigh, NC. 24 pp.

Packee, E. C. 1990. **Western hemlock.** *In:* Burns, R. M.; Honkala, B. H.; tech. coords. Silvics of North America: 1. Conifers. Agriculture Handbook 654. U.S. Department of Agriculture, Forest Service, Washington, D.C. p. 613-622.

Schroeder, P. E.; Dixon, R. K.; Winjum, J. K. 1993. **Forest management and agroforestry to sequester and conserve atmospheric carbon dioxide.** Unasylva 173, 44(2): 52-60.

Sleeth, P. 1994a. **Russian timber lures Northwest mills.** Associated Press, September 29.

Sleeth, P. 1994b. **Northwest mills set sights on South American forests.** Associated Press, October 3.

United Nations. 1996. **World Health Report.**

Western Wood Products Association (WWPA). 1995. **Statistical yearbook of the western lumber industry.** Western Wood Products Association, Portland, OR. 34 pp.

Whittenbury, C. G. 1997. **Changes in wood products manufacturing.** In: Kohm, K. A.; Franklin, J. F.; eds. Creating a forestry for the 21st century: the science of ecosystem management. Island Press, Washington, D.C. p. 303-314.

Wigley, T. M. L.; Raper, S. C. B. 1992. **Implications for climate and sea level of revised IPCC emissions scenarios.** Nature 357: 293-300.

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).

[1]Research Forester, Northeastern Forest Experiment Station, Portland, OR, and Project Leader, Rocky Mountain Research Station, Fort Collins, CO, respectively, U.S. Department of Agriculture, Forest Service.

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.

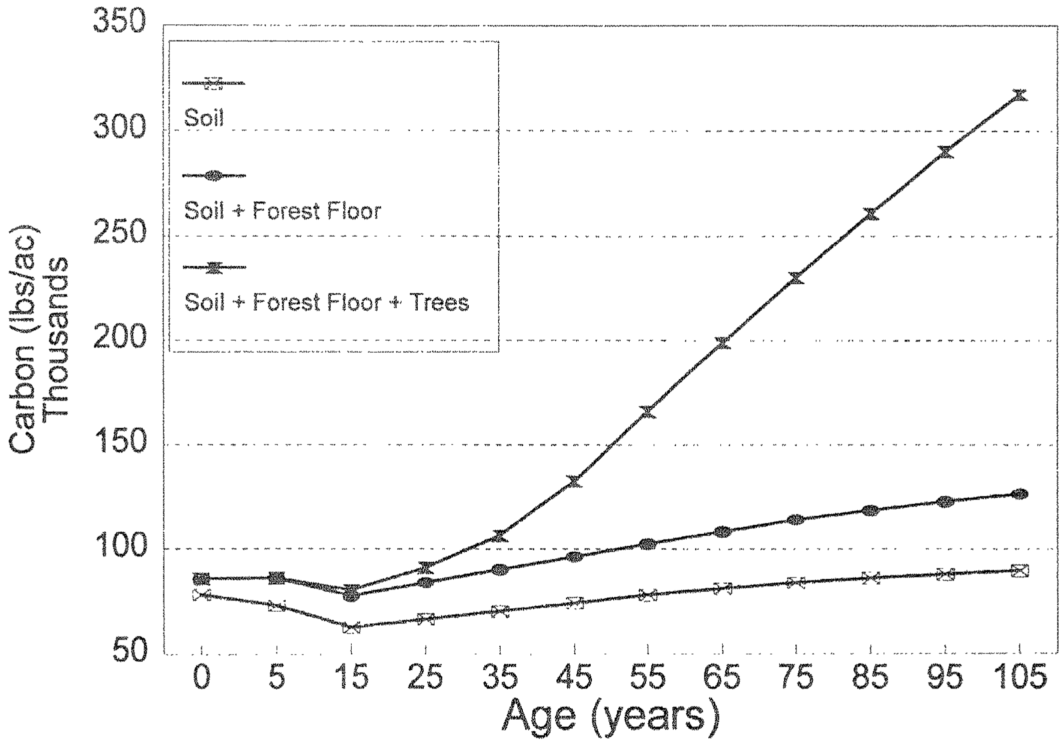


Figure 1.—Carbon changes over time for average Douglas-fir stands in the northern Rocky Mountains.

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.

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)

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.

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.

LITERATURE CITED

Birdsey, R. A. 1992. **Carbon storage and accumulation in United States forest ecosystems.** Gen. Tech. Rep. WO-59. Washington, DC: U. S. Department of Agriculture, Forest Service. 51 p.

Birdsey, R. A.; Heath, Linda S. 1995. **Carbon changes in U.S. forests.** In: Joyce, L. A., ed. Productivity of America's Forests and Climate Change. Gen. Tech. Rep. RM-GTR-271. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 56-70.

Brown, J. K.; See, T. E. 1981. **Downed and dead woody fuel and biomass in the Northern Rocky Mountains.** Gen. Tech. Rep. INT-117. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Experiment Station. 46 p.

Clinton, W. J.; Gore Jr, A. 1993. **The Climate Change Action Plan.** Washington, DC. 101 p.

Cost , N. D.; Howard, J.; Mead, B.; McWilliams, W. H.; Smith, W. B.; Van Hooser, D. D.; Wharton, E. H. 1990. **The biomass resource of the United States.** Gen. Tech. Rep. WO-57. Washington, DC: U.S. Department of Agriculture, Forest Service. 21 p.

Dixon, R. K.; Brown, S.; Houghton, R. A.; Solomon, A. M.; Trexler, M. C.; Wisniewski, J. 1994. **Carbon pools and flux of global forest ecosystems.** Science. 263: 185-190.

Haynes, R. W.; Adams, D. A.; Mills, J. R. 1995. **The 1993 RPA Timber Assessment Update.** Gen. Tech. Rep. RM-259. Ft. Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 66 p.

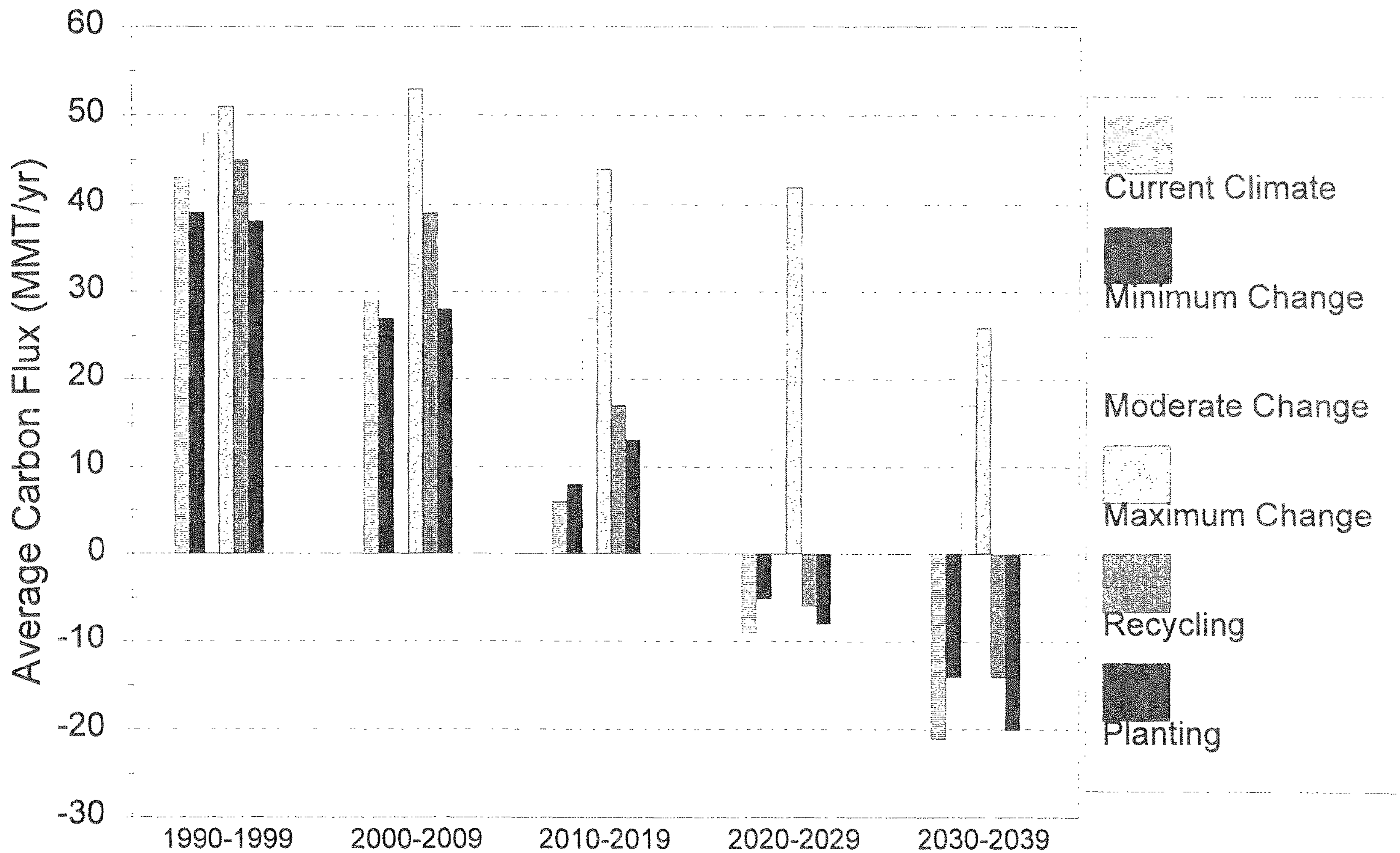


Figure 2.—Carbon flux for baseline, two alternative carbon sequestration scenarios, and three climate change scenarios.

Heath, Linda S.; Birdsey, Richard A. 1993. **Carbon trends of productive temperate forests of the coterminous United States.** Water, Air and Soil Pollution. 70: 279-293.

Heath, Linda S.; Birdsey, Richard A.; Row, Clark; Plantinga, Andrew J. 1996. **Carbon pools and fluxes in U.S. forest products.** In: Apps, M. J;. Price, D. T., eds. Forest Ecosystems, Forest Management and the Global Carbon Cycle. NATO ASI Series I: Global Environmental Change, Vol. 40, Springer-Verlag, Berlin: 271-278.

IPCC. 1995. **Climate Change 1995: the science of climate change.** In: Houghton, J. T.; Meira Filho, L. G.; Callander, B. A.; Harris, N.; Kattenberg, A.; Maskell, K., eds. Published for the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, MA. 572 p.

IPCC/OECD. 1994. **IPCC guidelines for national greenhouse gas inventories, 3 volumes.** Volume 1, reporting instructions; Volume 2, workbook; Volume 3, draft reference manual. Intergovernmental Panel on Climate Change, Organization for Economic Co-Operation and Development. Paris, France.

Joyce, L. A.; Mills, J. R.; Heath, L. S.; McGuire, A. D.; Haynes, R. W.; Birdsey, R. A. 1995. **Forest sector impacts from changes in forest productivity under climate change.** Journal of Biogeography. 22: 703-713.

McGuire, A. D.; Joyce, L. A. 1995. **Responses of net primary production to changes in carbon dioxide and climate.** In: Joyce, L. A., editor. Productivity of America's Forests and Climate Change. Gen. Tech. Rep. RM-271. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 9-45.

Melillo, J. M.; Prentice, I. C.; Farquhar, G. D.; Schulze, E. D.; Sala, O. E. 1995. **Terrestrial biotic responses to environmental change and feedbacks to climate.** Chapter 9. In: Houghton, J. T.; Meira Filho, L. G.; Callander, B. A.; Harris, N.; Kattenberg, A.; Maskell, K. eds. Climate Change 1995. The Science of Climate Change. Cambridge University Press.

Mills, J. R.; Kincaid, J. C. 1991. **The Aggregate Timberland Assessment System--ATLAS: A comprehensive timber projection model.** Gen. Tech. Rep. PNW-281. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 160 p.

Plantinga, A. J.; Birdsey, R. A. 1993. **Carbon fluxes resulting from U.S. private timberland management.** Climatic Change. 23: 37-53.

Powell, D. S.; Faulkner, J. L.; Darr, D. D.; Zhu, Z.; MacCleery, D. W. 1993. **Forest Resources of the United States, 1992.** Gen. Tech. Rep. RM-234. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 132 p.

U.S. Department of Agriculture, Forest Service. 1992. **1984-1990 Forest Fire Statistics.** Washington, DC: U.S. Department of Agriculture, Forest Service, State and Private Forestry, Fire and Aviation Staff.

U.S. Department of Energy (coord.). 1994. **The Climate Change Action Plan: Technical Supplement.** Washington, DC: U.S. Department of Energy, Office of Policy, Planning, and Program Evaluation. 148 p.

U.S. Environmental Protection Agency. 1994. **Inventory of U.S. greenhouse gas emissions and sinks: 1990-1993.** EPA 230-R-94-D14. Washington, DC: U.S. Environmental Protection Agency, Office of Policy, Planning, and Evaluation.

VEMAP members. 1995. **Vegetation/ecosystem modeling and analysis project: comparing biogeography and biogeochemistry models in a continental-scale study of terrestrial ecosystem responses to climate change and CO_2 doubling.** Global Biogeochemical Cycles. 9(4): 407-437.

Waddell, Karen L.; Oswald, Daniel D.; Powell, Douglas S. 1989. **Forest statistics of the United States, 1987.** Res. Bull. PNW-168. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 106 p.

Woudenberg, Sharon W; Farrenkopf, Thomas O. 1995. **The Westwide forest inventory data base: user's manual.** Gen. Tech. Rep. INT-GT-317. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 67 p.

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

David S. Buckley[1], John C. Zasada[1], John C. Tappeiner II[2], and Douglas M. Stone[3]

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

[1]Research Ecologist and Project Leader, respectively, North Central Forest Experiment Station, U.S. Department of Agriculture, Forest Service, Forestry Sciences Laboratory, Rhinelander, WI.
[2]Scientist, U.S. Department of the Interior, U.S. Geological Survey, Biological Resources Division, Forestry Sciences Laboratory, and Oregon State University, Corvallis, OR.
[3]Soil Scientist, North Central Forest Experiment Station, U.S. Department of Agriculture, Forest Service, Forestry Sciences Laboratory, Grand Rapids, MN.

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

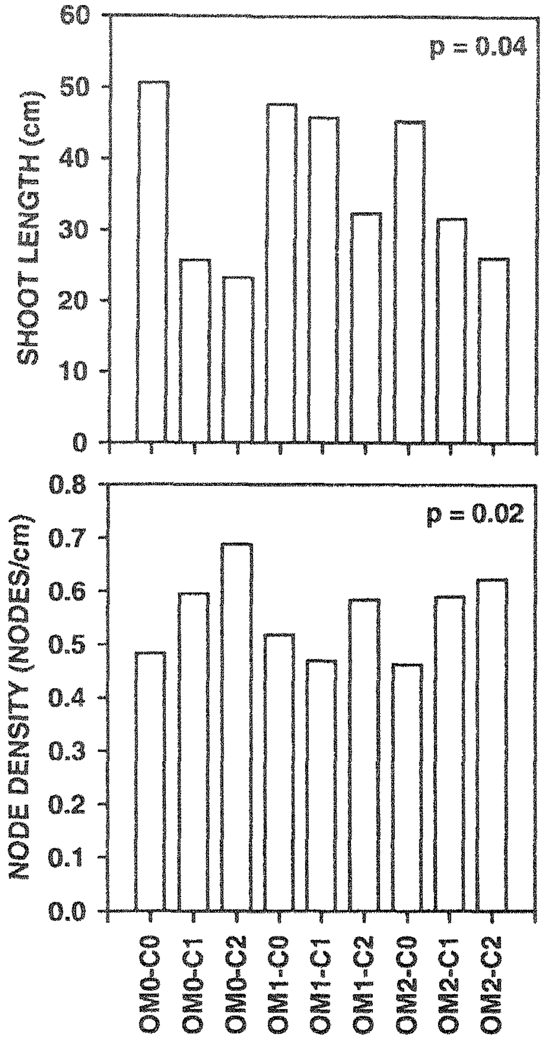


Figure 1.—Morphological differences in current-year shoots of equal-aged trembling aspen in response to combinations of organic matter removal and compaction treatments on a long term soil productivity site established on the Ottawa National Forest. Treatment codes are as follows: OM0 = no organic removal, 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.

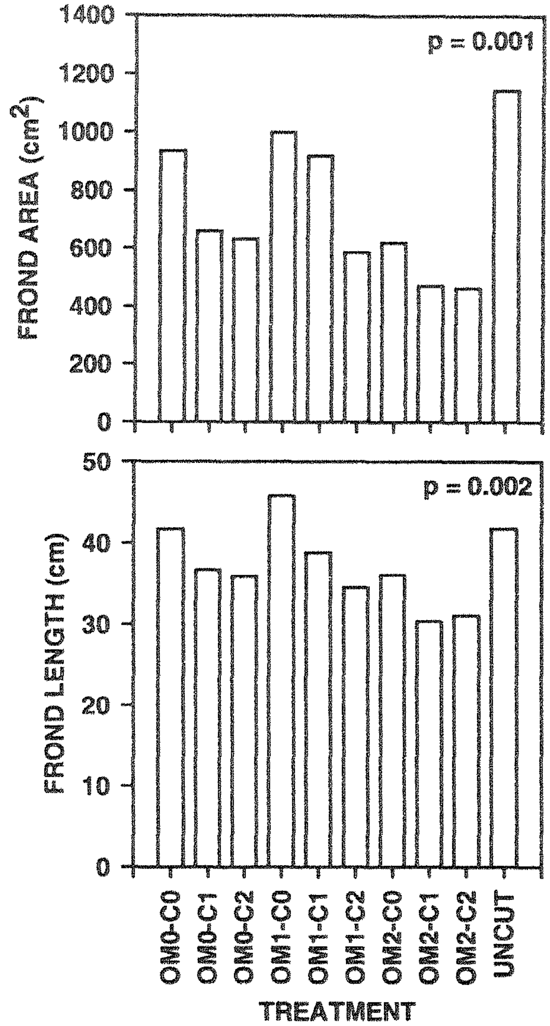


Figure 2.—Differences in morphological characteristics of bracken fern in response to combinations of organic matter removal and compaction treatments on a long term soil productivity site established on the Ottawa National Forest. Treatment codes as in Figure 1. Uncut = no organic matter removal, no 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.

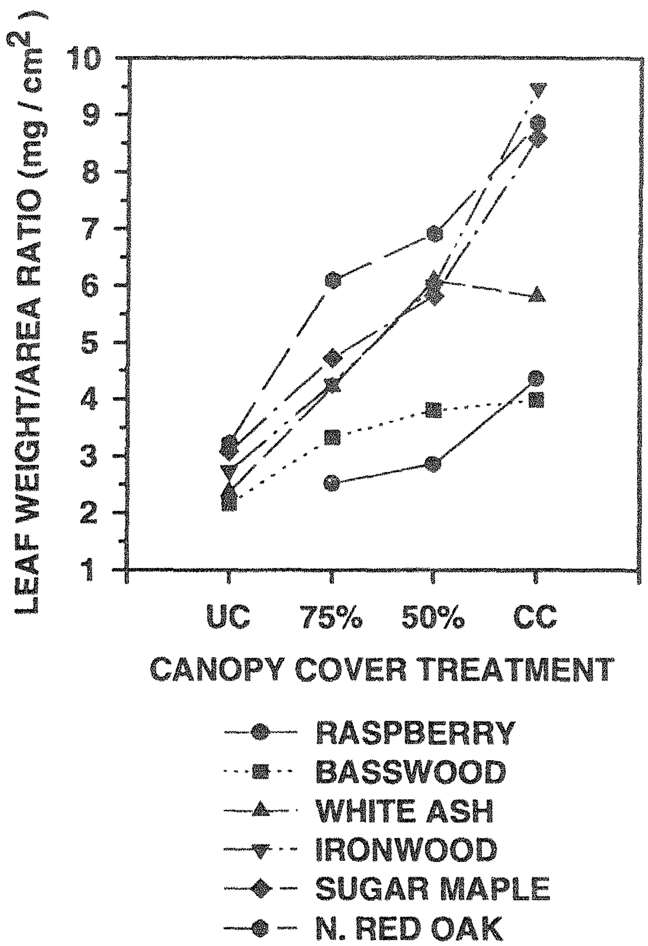


Figure 3.—Differences in leaf weight/area ratio of raspberry and five hardwood species across adjacent northern hardwood stands thinned and clearcut to achieve different amounts of canopy cover. Treatment codes are as follows: UC = uncut (control), 75% = 75% canopy cover, 50% = 50% canopy cover, and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

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.

LITERATURE CITED

Abrams, Marc D.; Kubiske, Mark E. 1990. **Leaf structural characteristics of 31 hardwood and conifer tree species in Central Wisconsin: influence of light regime and shade-tolerance rank.** For. Ecol. Manage., 31: 245-253.

Ashton, P. M. S.; Berlyn, G. P. 1994. **A comparison of leaf physiology and anatomy of *Quercus* (section *Erythrobalanus*-Fagaceae) species in different light environments.** Am. J. Bot., 81: 589-597.

Bell, Adrian D. 1991. **Plant form: An illustrated guide to flowering plant morphology.** New York, NY: Oxford University Press. 341 p.

Bonser, Stephen P.; Aarssen, Lonnie W. 1994. **Plastic allometry in young sugar maple (*Acer saccharum*): adaptive responses to light availability.** Am. J. Bot., 81: 400-406.

Canham, Charles David. 1988. **Growth and canopy architecture of shade tolerant trees: response to canopy gaps.** Ecology, 69: 786-795.

Coleman, James S.; McConnaughay, Kelly D. M.; Ackerly, David D. 1994. **Interpreting phenotypic variation in plants.** Tree, 9: 187-191.

Collins, B. S.; Dunne, K. P.; Pickett, S. T. A. 1985. **Responses of forest herbs to canopy gaps.** In: Pickett, S. T. A.; White, P. S., ed. The ecology of natural disturbance and patch dynamics. Orlando, FL: Academic Press. 472 p.

Dahlem, Theresa Schutte; Boerner, Ralph E. J. 1987. **Effects of canopy light gap and early emergence on the growth and reproduction of *Geranium maculatum*.** Can. J. Bot., 65: 242-245.

Goulet, France; Bellefleur, Pierre. 1986. **Leaf morphology plasticity in response to light environment in**

deciduous tree species and its implication on forest succession. Can. J. For. Res., 16: 1192-1195.

Hanson, P. J.; Dickson, R. E.; Isebrands, J. G.; Crow, T. R.; Dixon, R. K. 1986. **A morphological index of *Quercus* seedling ontogeny for use in studies of physiology and growth.** Tree Physiol., 2: 273-281.

Harper, John L. 1977. **Population biology of plants.** New York, NY: Academic Press. 892 p.

Harrington, Timothy B.; Tappeiner, John C., II. 1991. **Competition affects shoot morphology, growth duration, and relative growth rates of Douglas-fir saplings.** Can. J. For. Res., 21: 474-481.

Horn, Henry S. 1971. **The adaptive geometry of trees.** Princeton, NJ: Princeton University Press. 144 p.

Huffman, David W.; Zasada John C.; Tappeiner, John C., II. 1994a. **Growth and morphology of rhizome cuttings and seedlings of salal (*Gaultheria shallon*): effects of four light intensities.** Can. J. Bot., 72: 1702-1708.

Huffman, David W.; Tappeiner, John C., II; Zasada, John C. 1994b. **Regeneration of salal (*Gaultheria shallon*) in the central Coast Range forests of Oregon.** Can. J. Bot., 72: 39-51.

Jurik, Thomas W. 1986. **Temporal and spatial patterns of specific leaf weight in successional northern hardwood tree species.** Am. J. Bot., 73: 1083-1092.

Kramer, Paul J.; Kozlowski, Theodore T. 1979. **Physiology of woody plants.** New York, NY: Academic Press. 811 p.

Mattheck, Claus. 1995. **Biomechanical optimum in woody stems.** In: Gartner, Barbara L., ed. Plant stems: physiology and functional morphology. New York, NY: Academic Press. 440 p.

McDonald, Philip M.; Skinner, Carl N.; Fiddler, Gary O. 1992. **Ponderosa pine needle length: an early indicator of release treatment effectiveness.** Can. J. For. Res., 22: 761-764.

Niinemets, Ulo. 1996. **Plant growth-form alters the relationship between foliar morphology and species shade-tolerance ranking in temperate woody taxa.** Vegetatio, 124: 145-153.

Perala, Donald A. 1983. **Modeling aspen and red pine shoot growth to daily weather variations.** Res. Pap. NC-236. St. Paul, MN; U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 11 p.

Pickett, S. T. A.; Kempf, J. S. 1980. **Branching patterns in forest shrubs and understory trees in relation to habitat.** New Phytol., 86: 219-228.

Sipe, T. W.; Bazzaz, F. A. 1994. **Gap partitioning among maples (*Acer*) in central New England: shoot architecture and photosynthesis.** Ecology, 75: 2318-2332.

Stafstrom, Joel P. 1995. **Developmental potential of shoot buds.** In: Gartner, Barbara L., ed. Plant stems: physiology and functional morphology. New York, NY: Academic Press. 440 p.

Tappeiner, John C., II; Hughes, Thomas F.; Tesch, Steven D. 1987. **Bud production of Douglas-fir (*Pseudotsuga menziesii*) seedlings: response to shrub and hardwood competition.** Can. J. For. Res. 17: 1300-1304.

Waller, Donald M.; Steingraeber, David A. 1995. **Opportunities and constraints in the placement of flowers and fruits.** In: Gartner, Barbara L., ed. Plant stems: physiology and functional morphology. New York, NY: Academic Press. 440 p.

Watson, M. A.; Casper, B. B. 1984. **Morphological constraints on patterns of carbon distribution in plants.** Ann. Rev. Ecol. Syst. 15: 233-258.

White, J. 1979. **The plant as a metapopulation.** Ann. Rev. Ecol. Syst., 10: 109-145.

Wilson, Brayton F. 1995. **Shrub stems: form and function.** In: Gartner, Barbara L., ed. Plant stems: physiology and functional morphology. New York, NY: Academic Press. 440 p.

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,

[1]Research forester, Biologist, and Project Leader, respectively, U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station, Forestry Sciences Laboratory, Rhinelander, WI.

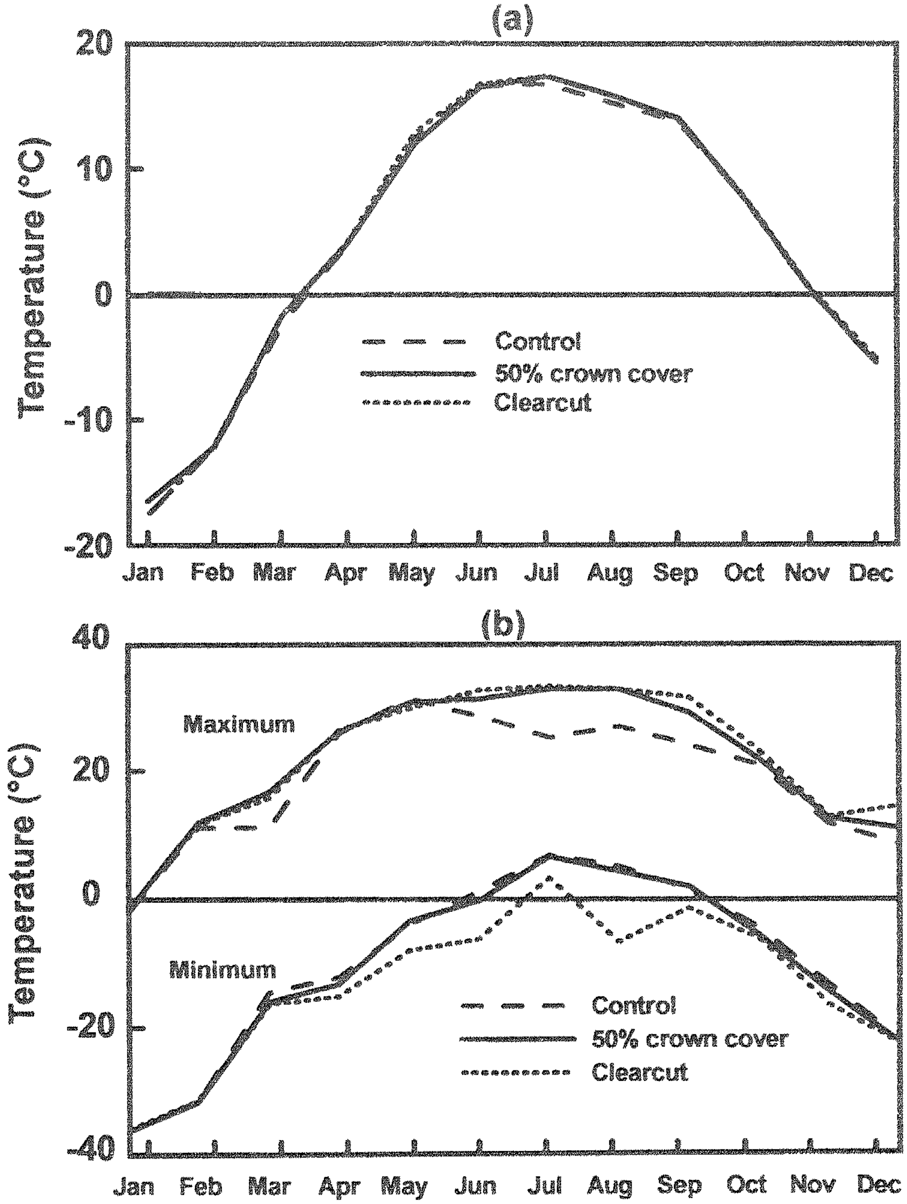


Figure 1.—Average (a) and maximum and minimum (b) monthly temperatures for the control, 50 percent crown cover, and clearcut treatments in the partial cutting study 1.0 m above the ground, 1994.

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

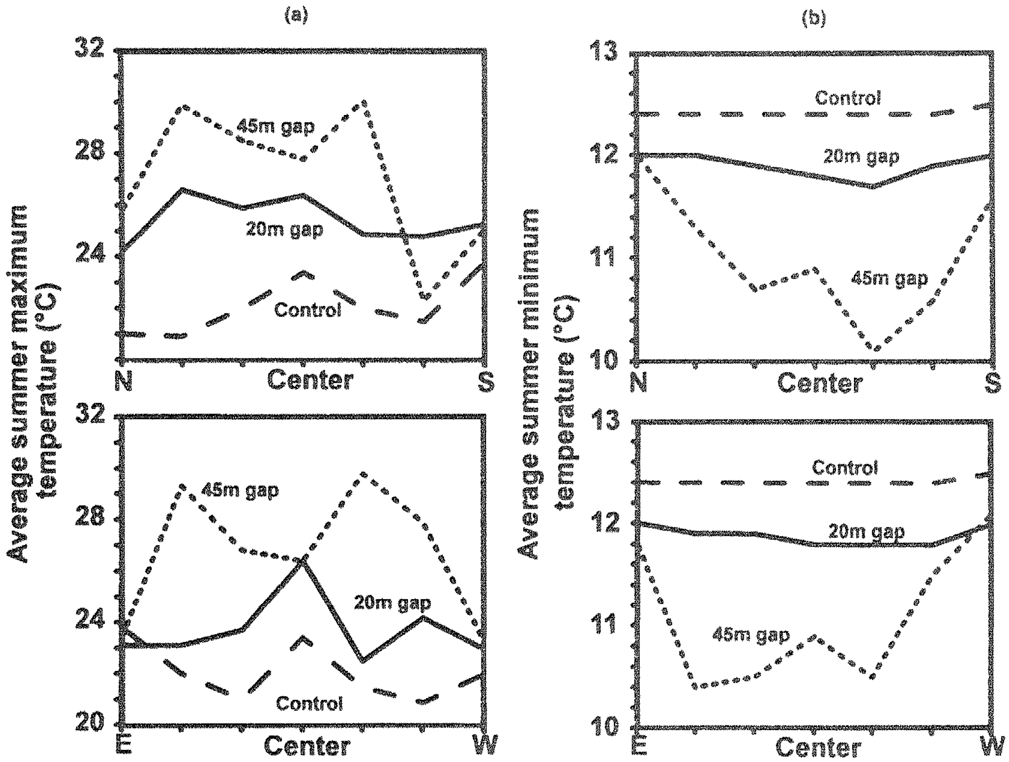


Figure 2.—Average summer maximum (a) and minimum (b) temperatures for the control, 20-m gap, and 45-m gap treatments in the canopy gap study 0.1 m above the ground, 1995.

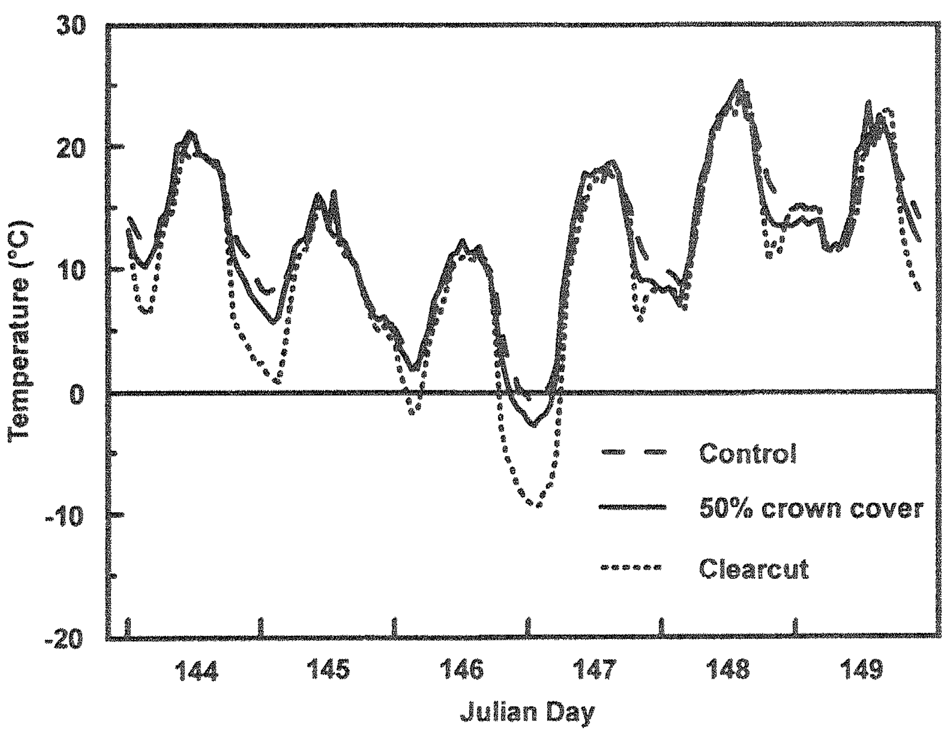


Figure 3.—Minimum temperatures in the partial cutting study for the control, 50 percent crown cover, and clearcut treatments, May 26-27, 1994.

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

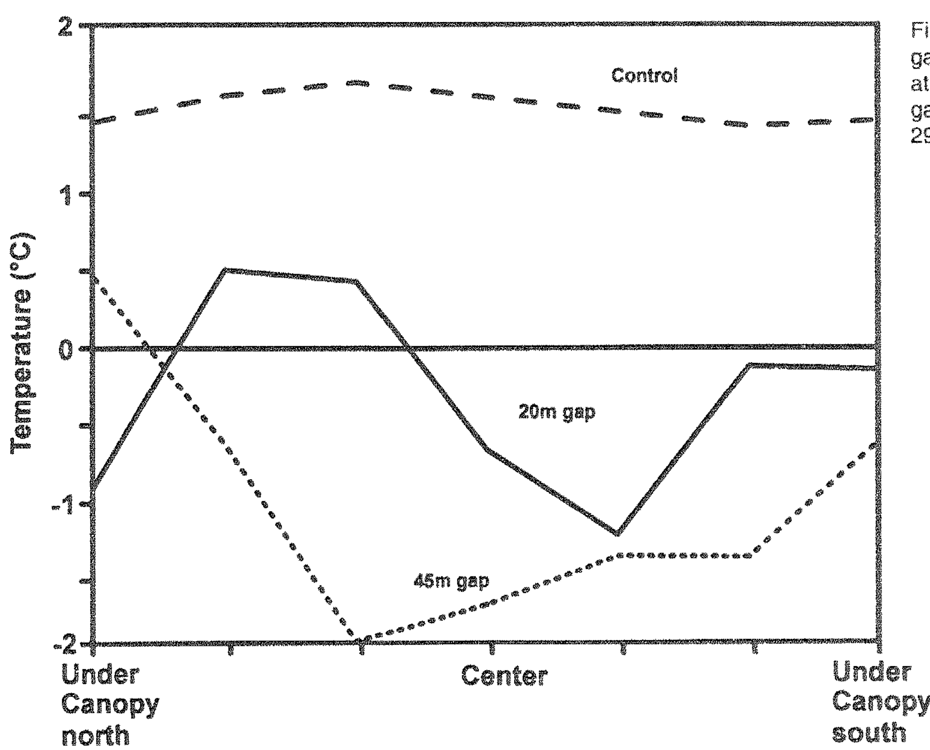


Figure 4.—Frost event in the canopy gap study 0.1 m above the ground at the center of the control, 20-m gap, and 45-m gap treatments, May 29, 1995.

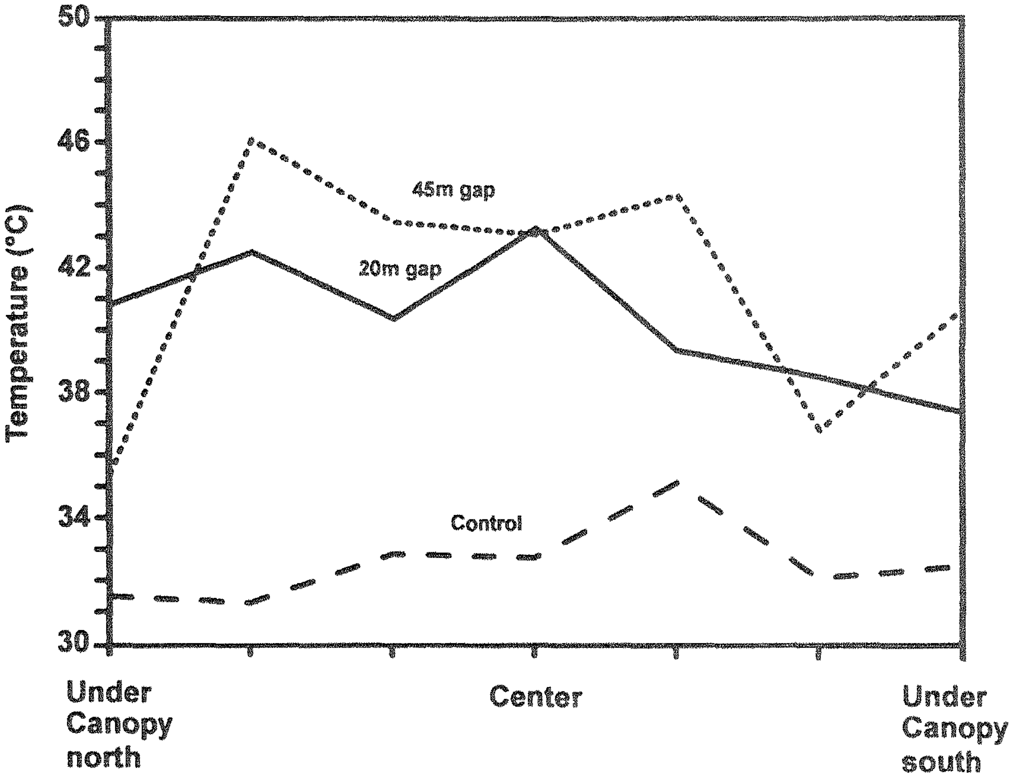


Figure 5.—Extreme high temperature events in the canopy gap study 0.1 m above the ground at the center of the control, 20-m gap, and 45-m gap treatments, June 18, 1995.

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.

LITERATURE CITED

Arbogast, Carl, Jr. 1957. **Marking guides for northern hardwoods under the selection system.** Stn. Pap. 56. St. Paul, MN: U.S. Department of Agriculture, Forest Service, Lake States Forest Experiment Station. 20 p.

Burns, Russell M.; Honkala, Barbara H. 1990. **Silvics of North America; Hardwoods.** Agric. Hand. 654. Washington DC: U.S. Department of Agriculture, Forest Service. 877 p. Vol. 2.

Canham, Charles D.; Loucks, Orie L. 1984. **Catastrophic windthrow in the presettlement forests of Wisconsin.** Ecology 65: 803-809.

Erdmann, Gayne G. 1986. **Developing quality in second growth stands.** In: Mroz, Glenn D.; Reed Dave D., eds. Proceedings of the conference on the northern hardwood resource: management and potential, 18-20, Houghton, MI: August 1986; Houghton, Mich. Michigan Technological University: 206-222.

Frelich, Lee E.; Lorimer, Craig G. 1991. **Natural disturbance regimes in hemlock-hardwood forests of the Upper Great Lakes region.** Ecological Monographs. 61: 145-164.

Geiger, R. 1965. ***Climate near the ground.*** Harvard University Press. 611 p.

Lorimer, Craig G.; Frelich, Lee E. 1994. **Natural disturbance regimes in old-growth northern hardwoods.** Journal of Forestry. 92: 33:38.

Niese, Jeff N.; Strong, Terry F.; Erdmann Gayne G. 1995. **Forty years of alternative management practices in second growth-, pole-size northern hardwoods. II. Economic evaluation.** Canadian Journal of Forest Research. 25: 1180-1188.

Rinnger, Diane L. 1972. **The microclimate of various forest openings.** MS Thesis. University of Wisconsin-Milwaukee. 122 p.

Rinnger, Diane L.; Stearns, Forest W. 1972. **Influence of forest openings on climate.** University of Wisconsin-Milwaukee Field Station Bulletin. 5: 9-13.

Strong, Terry F.; Erdmann, Gayne G.; Niese, Jeff N. 1995. **Forty years of alternative management practices in second growth-, pole-size northern hardwoods. I. Tree quality development.** Canadian Journal of Forest Research. 25: 1173-1179.

Tubbs, Carl H. 1977. **Manager's handbook for northern hardwoods in the North Central States.** Gen. Tech. Rep. NC-39. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 29 p.

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.
[2]Dr. Piirto is a Professor and Registered Professional Forester, Natural Resources Management Department, California Polytechnic State University, San Luis Obispo, CA 93407. Mr. Rogers is a Registered Professional Forester and Giant Sequoia Specialist for the USDA Forest Service, Sequoia National Forest, 900 West Grand Avenue, Porterville, CA , 93257. Ms. Mary Chislock Bethke is the Public Affairs Officer and Giant Sequoia Program Manager for Sequoia National Forest (same address as that shown for Mr. Rogers).

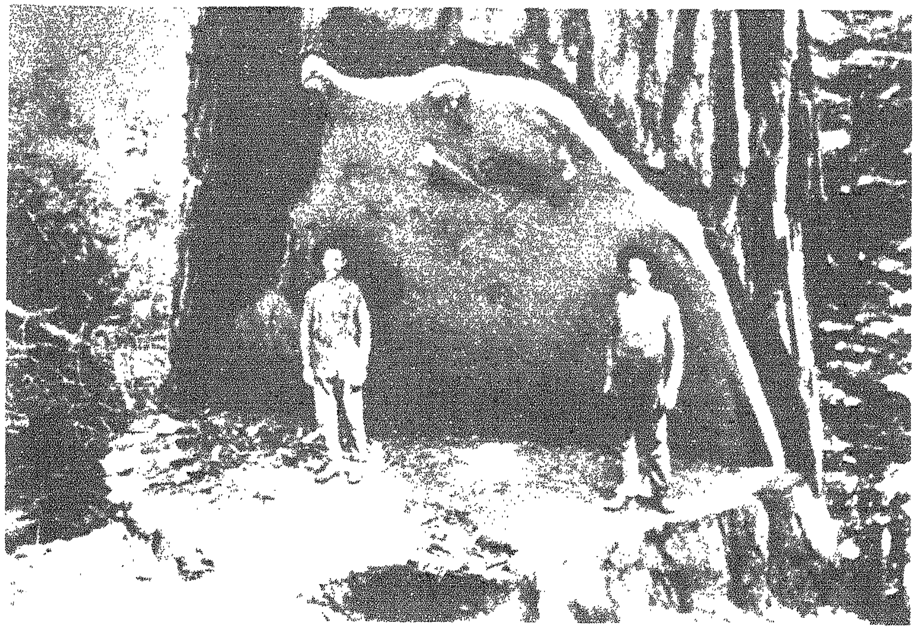


Figure 1.—This Mark Twain tree stood on privately owned land when it was cut in 1891 for museum exhibition purposes. The logged over area now known as the Big Stump grove is under the federal jurisdiction and protection of Sequoia National Forest. (Stauffer Publishing Co. photo).

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

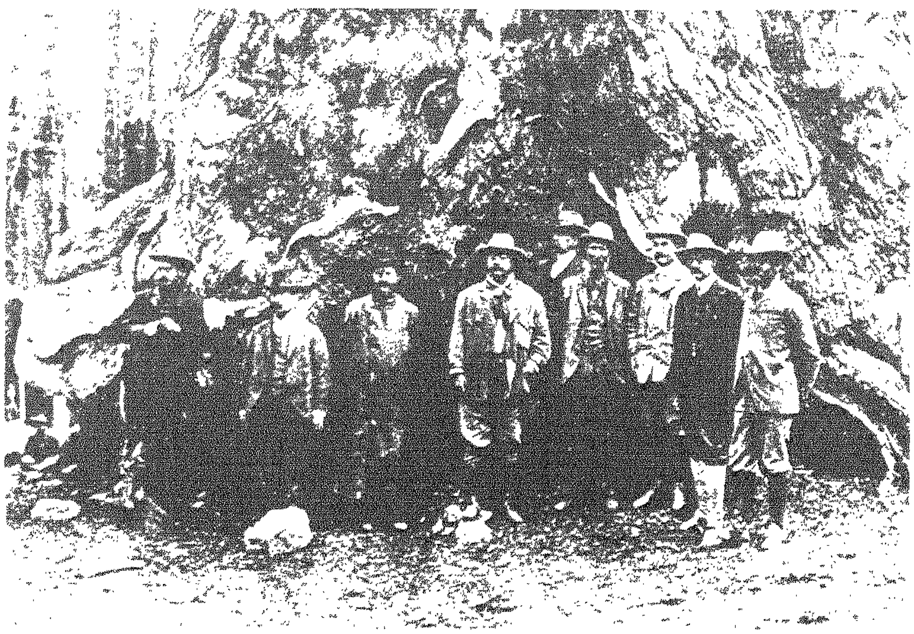


Figure 3.—John Muir, President Teddy Roosevelt, and a group of people at the base of a giant sequoia in Yosemite National Park in 1903 (Harcourt Brace Co. photo).

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

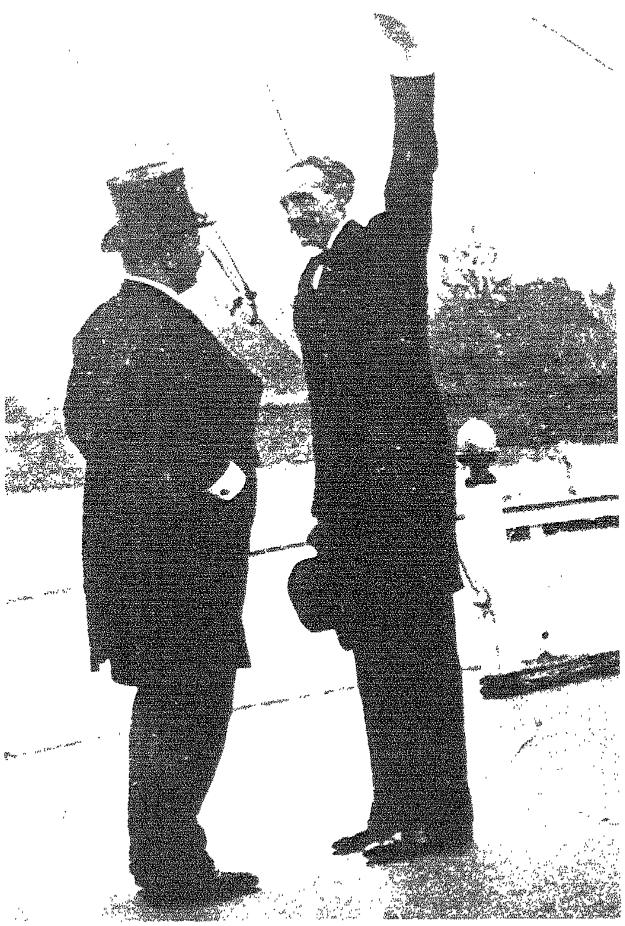


Figure 4.—Pinchot and Roosevelt conferring during an Inland Waterways Commission trip on the Mississippi River in October 1907 (Harcourt Brace Publishing Co. photo).

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

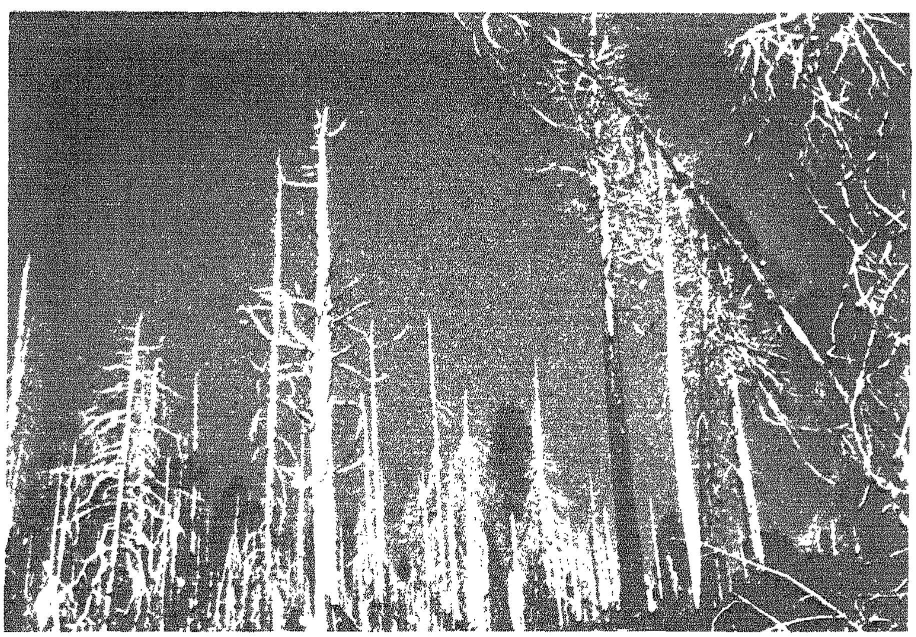


Figure 6.—The results of a National Park Service prescribed burn in Redwood Mountain.

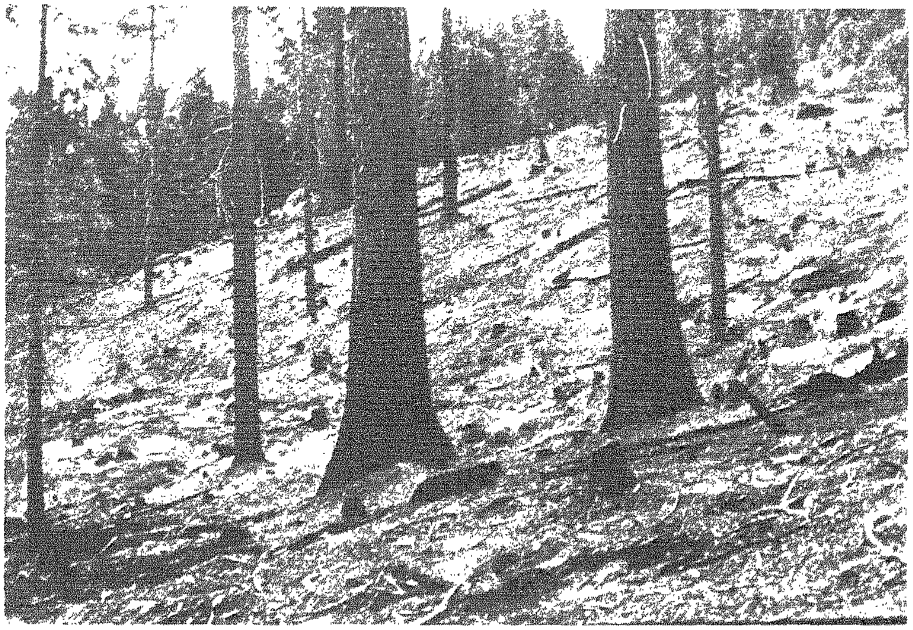


Figure 7.—Silvicultural treatments were completed on 15 acres of the Bearskin grove, Hume Lake Ranger District, Sequoia National Forest.

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

I thank the U.S.Department of Agriculture-Forest Service and the McIntire Stennis program for providing financial assistance to develop this paper. Acknowledgment is given to the individuals, agencies, and organizations which recently agreed to form the Giant Sequoia Ecology Cooperative. This cooperative was formed to provide leadership in applied research on the ecology of giant sequoia-mixed conifer

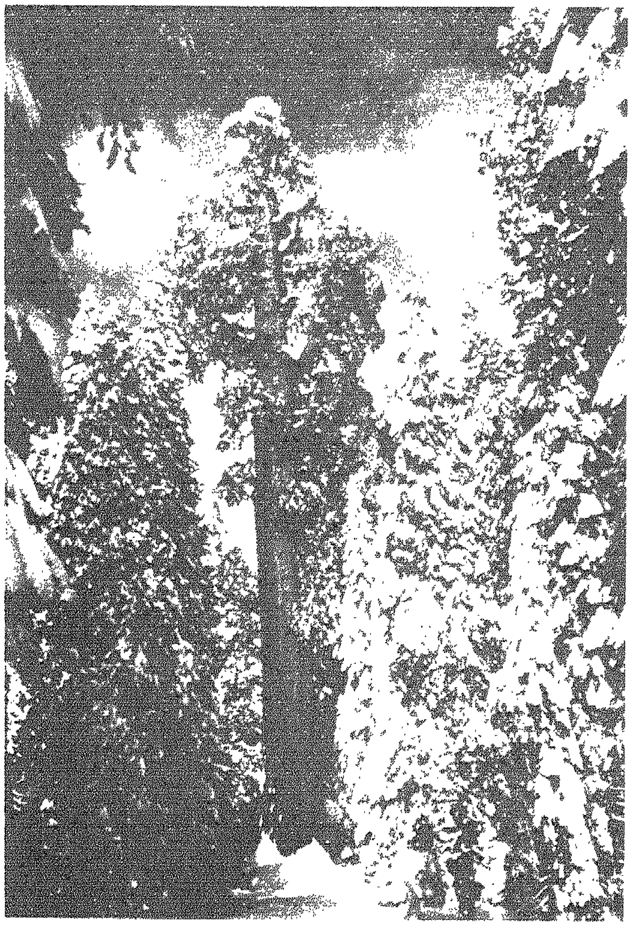


Figure 9.—The General Grant Tree in Sequoia-Kings Canyon National Park. A relic of the past or an icon to the future, the choice is ours to make.

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.

LITERATURE CITED

Aune, P. S., ed. 1994. **Proceedings of the symposium on giant sequoias: their place in the ecosystem and society**; 1992 June 23-25; Visalia, CA. Gen. Tech. Rep. PSW-151. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 170 p.

Harvey, T. H. 1985. **Evolution and history of giant sequoia.** In: Weatherspoon, P. C.; Iwamoto, Y.; Piirto, D. D., tech. coords. Proceedings of the workshop on management of giant sequoia; 1985 May 24-25, Reedley, CA. Gen. Tech. Rep. PSW-95. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station.

Hull, K. L. 1989. **The 1985 south entrance and Mariposa grove archaeological excavations.** Final report.

Johnston, H. 1996. **They felled the redwoods.** Stauffer Publishing Co.

Ornduff, R. 1994. **A botanist's view of the Big Tree.** In: Aune, P. S. Proceeding of the symposium on giant sequoias: their place in the ecosystem and society; 1992 June 23-25; Visalia, CA. Gen. Tech. Rep. PSW-151. Albany, CA. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station.

Piirto, D. D. 1991. **Giant sequoia groves, a relic to be preserved or a resource to be managed.** Witness statement presented at the September 4, 1991, hearing of the Congressional Committee on Interior and Insular Affairs, Visalia, CA.

Piirto, D. D. 1994. **Giant sequoia insect, disease, and ecosystem interactions.** In: Aune, P. S. 1994. Proceeding of the symposium on giant sequoias: their place in the ecosystem and society; 1992 June 23-25; Visalia, CA. Gen. Tech. Rep. PSW-151. Albany, CA. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station.

Piirto, D. D.; Cobb, F. W. Jr.; Workinger, A.; Otrosina, W. J.; Parmeter, J. R. Jr. 1992a. **Final report. biological and management implications of fire/pathogen interactions in the giant sequoia ecosystem; part II pathogenicity and genetics of *Heterobasidion annosum*.** San Luis Obispo, CA: California Polytechnic State University, Natural Resources Management Department.

Piirto, D. D.; Piper, K.; Parmeter, J. R. Jr. 1992b. **Final report: biological and management implications of fire/pathogen interactions in the giant sequoia ecosystem; part I—fire scar/pathogen studies.** San Luis Obispo, CA: California Polytechnic State University, Natural Resources Management Department.

Pinchot, Gifford. 1947. **Breaking new ground.** New York: Harcourt Brace Co.

Ticknor, W. D. 1993. **Sustainable forestry: redefining the role of forest management.** In: Aplet, H., N. Johnson, J. T. Olson, and V. Alaric Sample. Defining sustainable forestry. Island Press: 260-269.

University of California, Centers for Water and Wildland Resources. 1996. **Sierra Nevada Ecosystem Project, final report to Congress, vol.** assessment summaries and management strategies.

Weatherspoon, P. C. 1986. **Silvics of giant sequoia.** In: Weatherspoon, P. C.; Iwamoto. Y.; Piirto, D. D., tech. coords. Proceedings of the workshop on management of giant sequoia; 1985 May 24-25, Reedley, CA. Gen. Tech. Rep. PSW-95. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station.

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.

[1]Selective Breeding Specialist, USDA Forest Service, Northern, Intermountain, and Rocky Mountain Regions, Moscow, ID.

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.

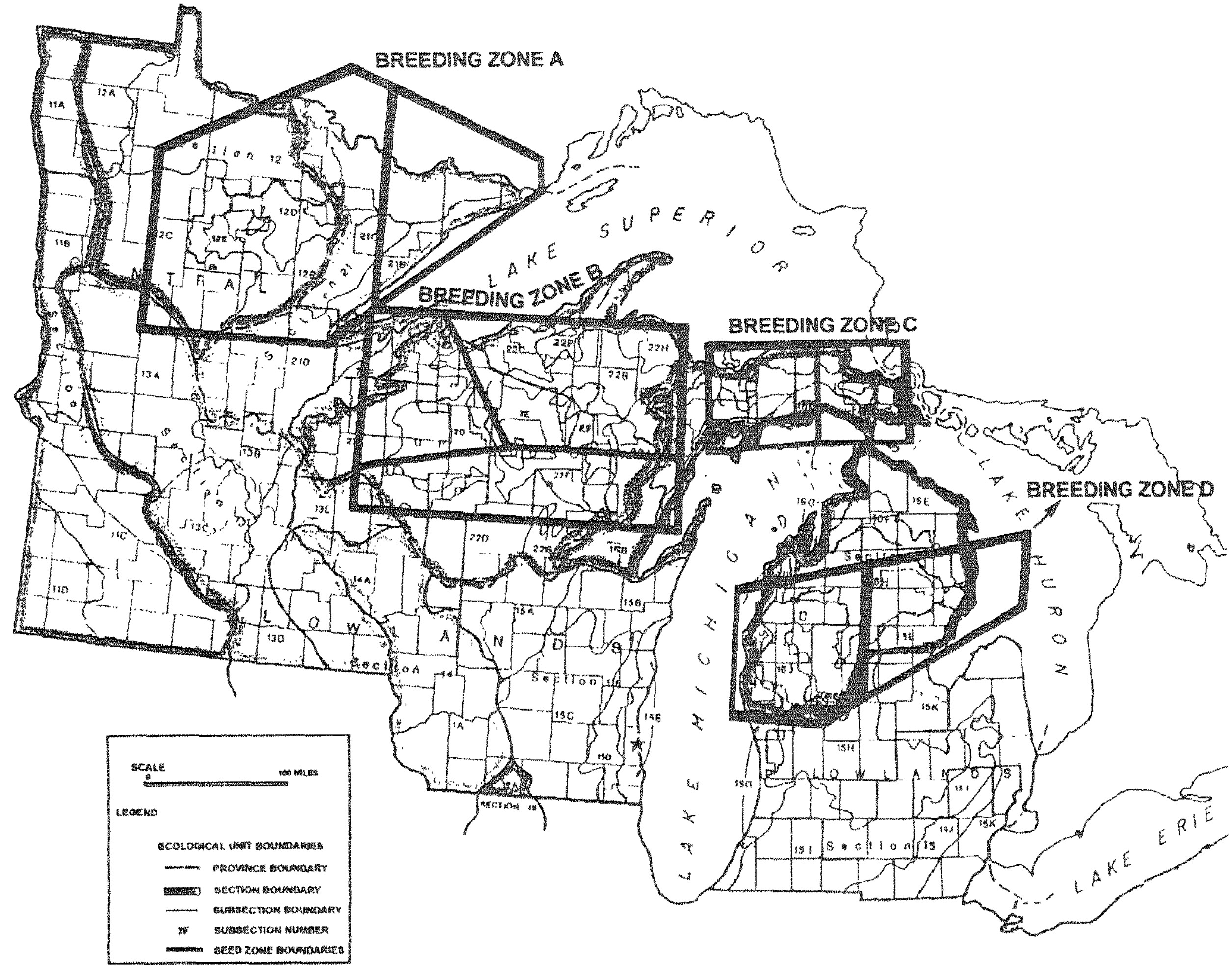


Figure 1.—Lake States breeding and seed zones superimposed on sections of the ecological classification system, USDA Forest Service Eastern Region.

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).

[2]Personal communication, Dr. Richard Meier, Regional Geneticist, USDA Forest Service, Eastern Region, Rhinelander, WI.

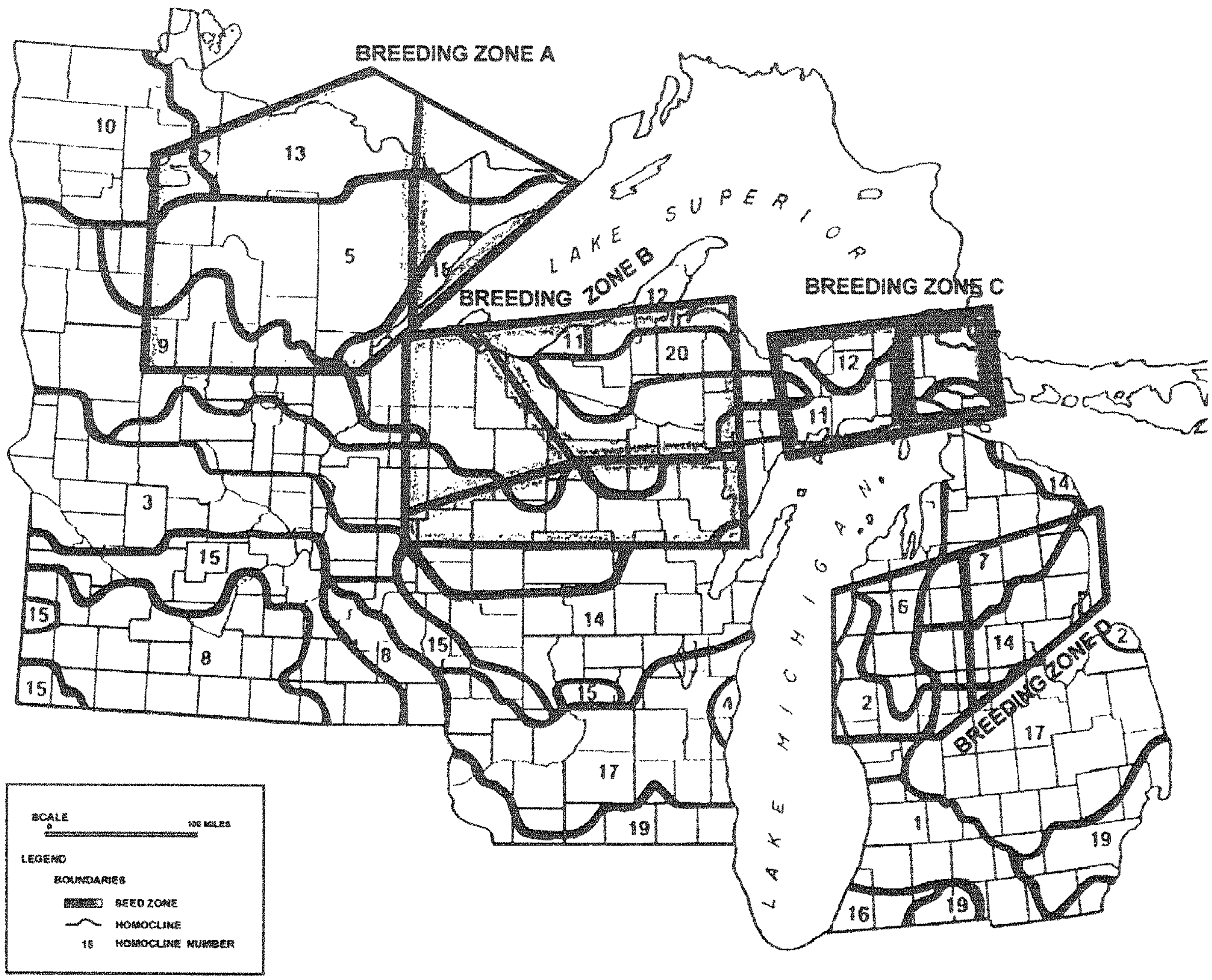


Figure 2.—Lake States breeding and seed zones superimposed on Lake States homoclines (Rauscher 1983), USDA Forest Service Eastern Region.

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.

ACKNOWLEDGMENTS

The author is grateful for the jack pine slides and seed source analysis provided by Dr. Richard Meier, graphics assistance provided by Mr. John Snakenburg and Martin Ramirez, and for critique of this article by Drs. Sheila Martinson and Gerald Rehfeldt.

LITERATURE CITED

Campbell, R. K.; Franklin, J. F. 1981. **A comparison of habitat type and elevation for seed-zone classification of Douglas-fir in western Oregon.** Forest Sci. 27(1): 49-59.

DeWald, L. E.; Mahalovich, M. F. 1997. **The role of forest genetics in managing ecosystems.** J. For. 4:12-16.

Hamrick, J. L.; Linhart, Y. B.; Mitton, J. B. 1979. **Relationships between life history characteristics and electrophoretically detectable genetic variation in plants.** Ann. Rev. Ecol. Syst.10:173-200.

Howe, G. E.; Raettig, T. L. 1985. **The forest tree improvement program for the Northern Region.** Alternative levels. USDA Forest Service Northern Region, 56 pp and appendices.

Khalil, M. A. 1985. **Genetic variation in eastern white spruce (*Picea glauca* (Moench) Voss) populations.** Can. J. For. Res. 15:444-452.

Mahalovich, M. F. 1995. **The role of genetics in improving forest health.** *In*: Proc. 1995 National Silviculture Workshop: Forest Health Through Silviculture. Mescalero, NM, May 8-11, 1995. Gen. Tech. Rep. RM-GTR-267. Ft. Collins, CO: USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, p 200-207.

Mahalovich, M. F. 1993. **NATGEN: An application of genetic principles to natural regeneration.** *In* Proc. 22nd Southern Forest Tree Improvement Conference. Atlanta, GA June 14-17, 1993. Sponsored Publication No. 44 of the Southern Forest Tree Improvement Committee, pp 214-221.

Millar, C. 1989. **Allozyme variation of bishop pine associated with pygmy-forest soils in northern California.** Can. J. For. Res. 19:870-879.

Mitton, J. B. 1995. **Genetics and the physiological ecology of conifers.** *In*: Ecophysiology of Coniferous Forests, W.K. Smith and T.M. Hinckley eds. Academic Press, Inc. San Diego, CA, pp 1-62.

Mitton, J. B.; Stutz, H. P.; Schuster, W. S.; Shea, K. L. 1989. **Genotypic differentiation at PGM in Engelmann spruce from wet and dry sites.** Silvae Genetica 38:217-221.

Murphy, D. D.; Freas, K. E.; Weiss, W. B. 1990. **An environment-metapopulation approach to population viability analysis for a threatened invertebrate.** Conservation Biology 4(1):41-51.

Neale, D. B. 1985. **Genetic implications of shelterwood regeneration of Douglas-fir in southwest Oregon.** Forest Sci. 31(4):995-1005.

Rauscher, H. M. 1983. **Homogeneous macro climatic zones in the Lake States.** USDA Forest Service North Central Forest Experiment Station, St. Paul, MN NC-RP 240, 39 p.

Rehfeldt, G. E. 1997. **Quantitative analyses of the genetic structure of closely related conifers with disparate distributions and demographics: the *Cupressus arizonica* (Cupressaceae) complex.** American J. Botany 84(2):190-200.

Rehfeldt, G. E. 1990. **Genetic resource management: using models of genetic variation in silviculture.** *In*: Proc. Genetics/Silviculture Workshop, Wenatchee, WA August 27-31, 1990, p 31-44.

Rehfeldt, G. E. 1974a. **Local differentiation of populations of Rocky Mountain Douglas-fir.** Can. J. For. Res. 4(3): 399-406.

Rehfeldt, G. E. 1974b. **Genetic variation of Douglas-fir in the northern Rocky Mountains.** USDA Forest Service, Intermountain Forest and Range Experiment Station, Research Note INT-184 6 p.

Savolainen, O.; Kärkkäinen, K. 1992. **Effect of forest management on gene pools.** New Forest 6:329-345.

USDA Forest Service. 1987. **Forest Plan**, Clearwater National Forest, September 1987, Orofino, Idaho.

USDA Forest Service. **Seed Handbook.** FSH 2409.26f. Eastern Region, Milwaukee, WI.

Yazdani, R.; Mouna, O.; Rudin, D.; Szmidt, A. E. 1985. **Genetic structure of *Pinus sylvestris* L. Seed-tree stand and naturally regenerated understory.** Forest Sci. 31(2):430-436.

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 SIMulating Vegetative Patterns and Processes at Landscape ScaLEs; 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

[1]Forest Silviculturist, USDA Forest Service, Lewis and Clark National Forest, Great Falls, MT 59401and Forester, USDA Forest Service, Rocky Mountain Research Station, Missoula, MT, respectively.

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

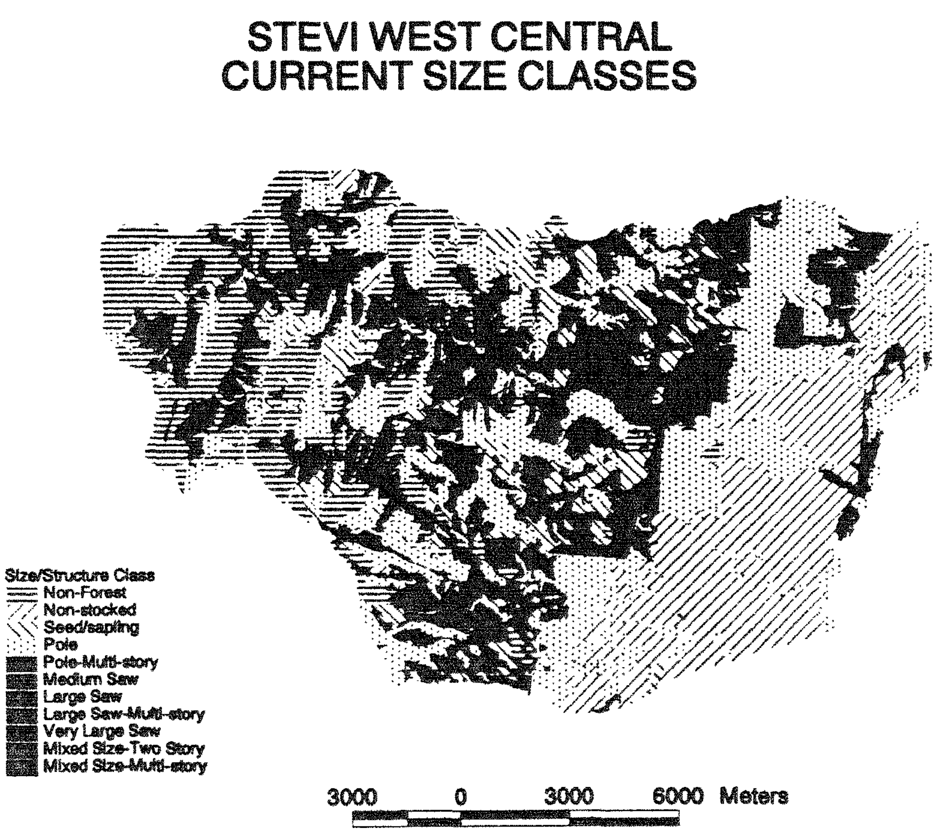


Figure 1.—Distribution of the Current Condition size and structure classes in the Stevi West Central project area. (Single story structure except as noted in legend.)

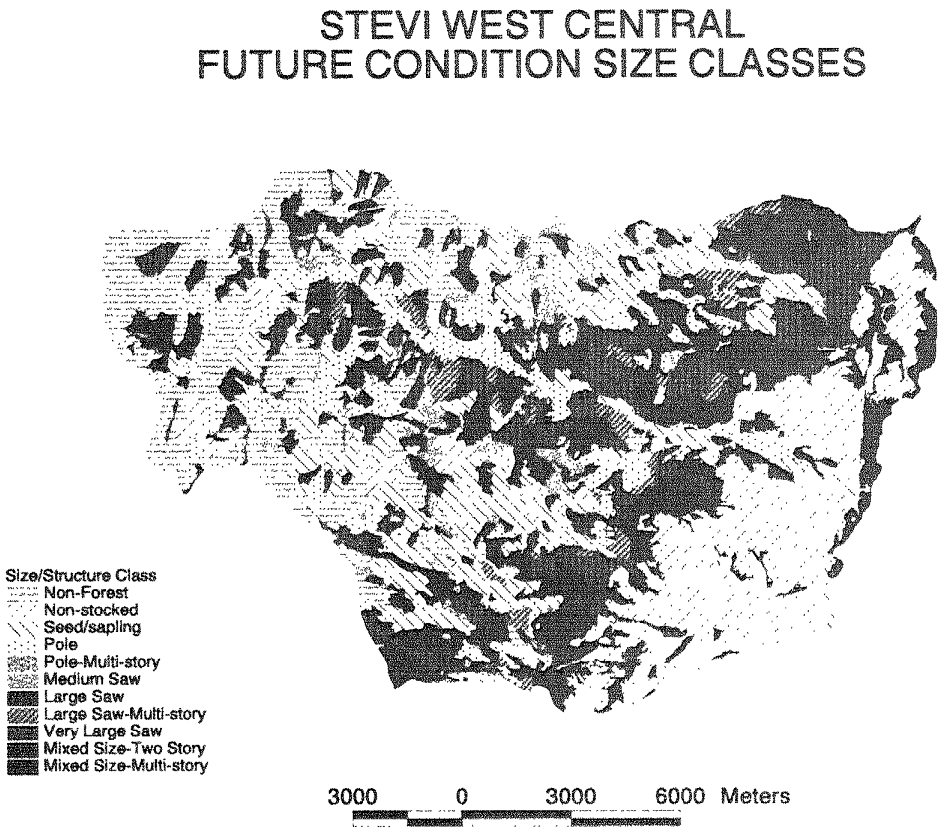


Figure 2.—Simulation of Future Condition in 50 years displaying size and structure classes with the only management activity being the current fire suppression. (Single story structure except as noted in legend.)

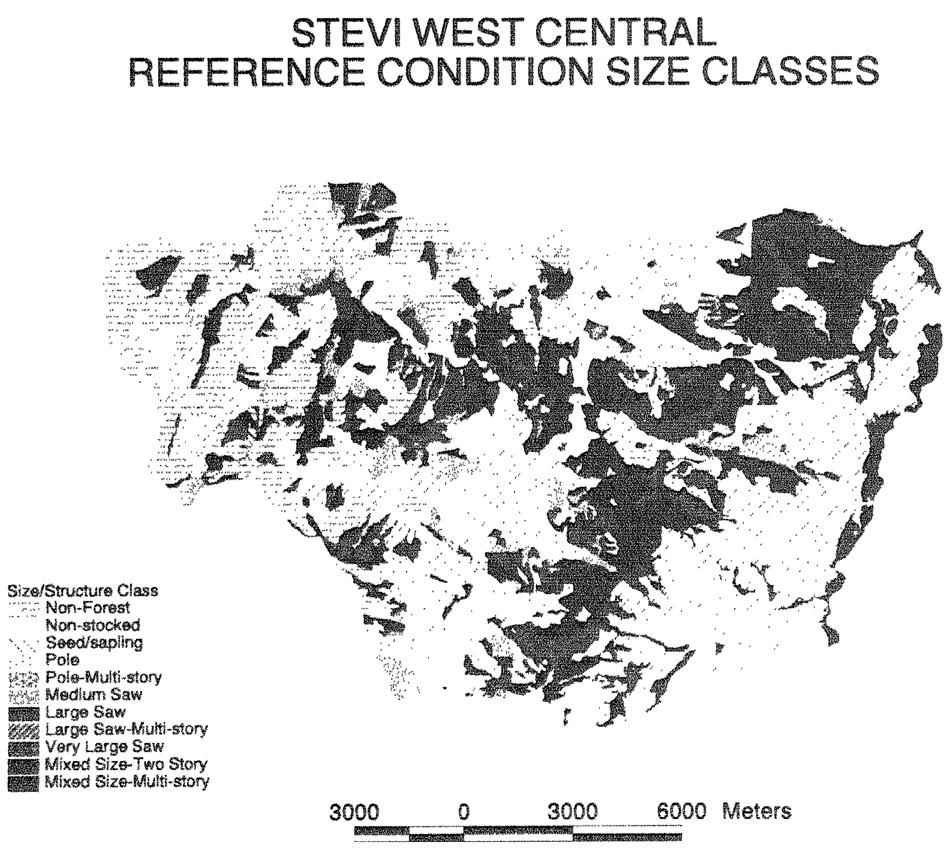


Figure 3.—Simulation of Reference Condition displaying distribution of size and structure classes. (Single story structure except as noted in legend.)

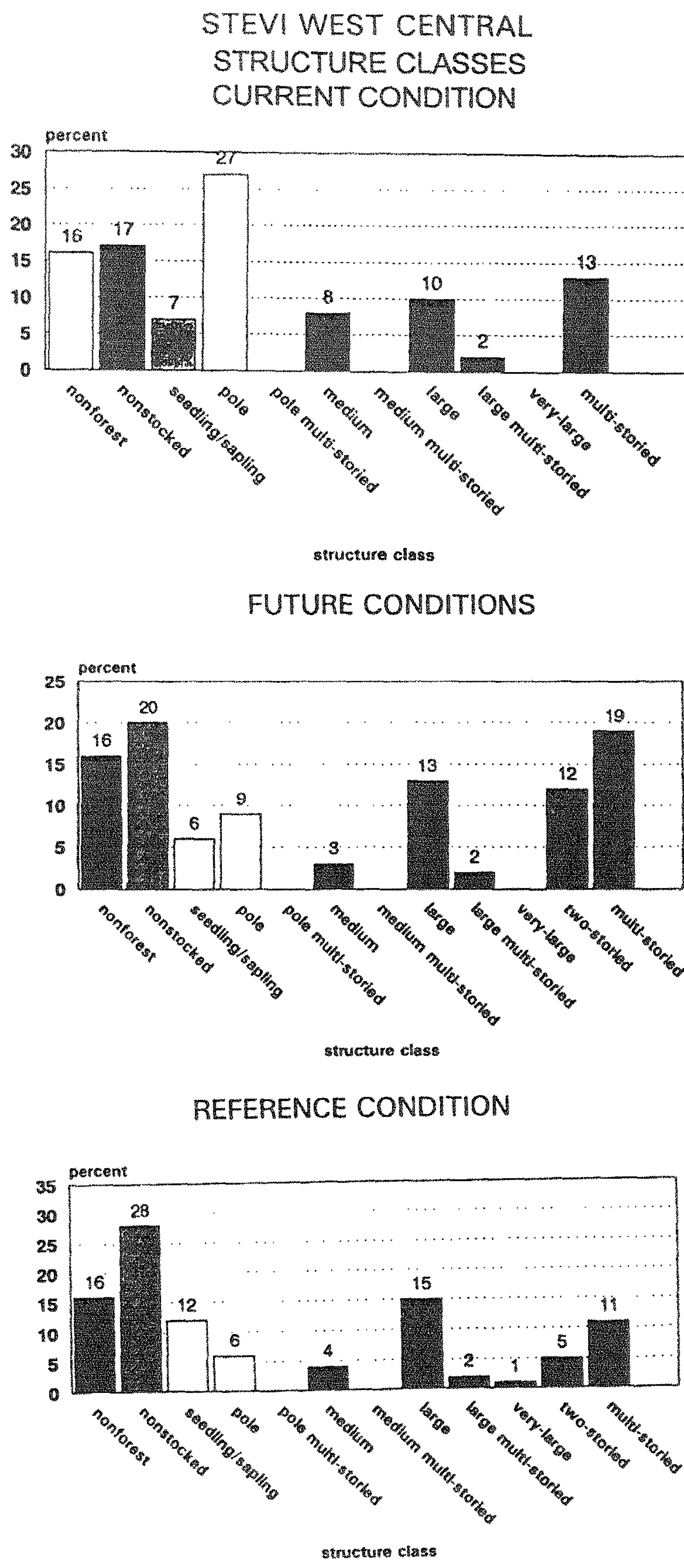


Figure 4.—Comparison of the size and structure classes in the three conditions: Current, Future (fire suppression only), and Reference Condition.

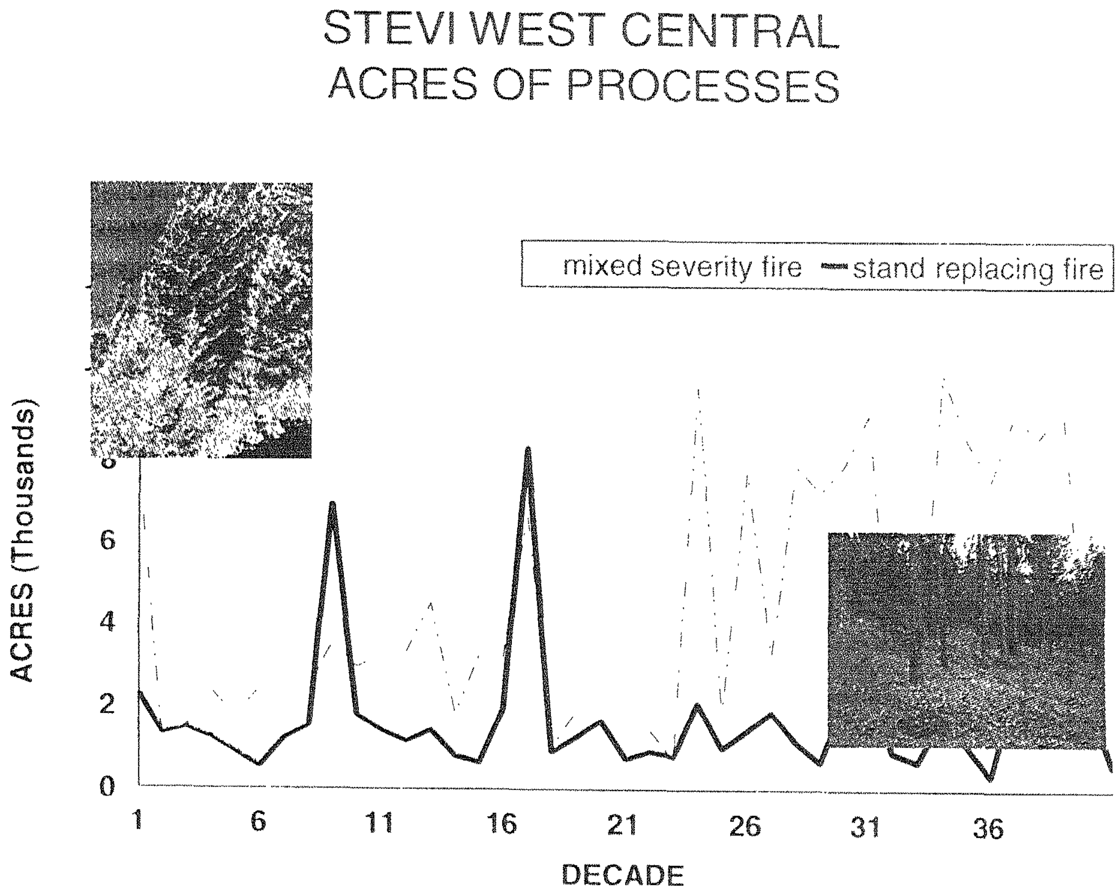


Figure 5.—Prediction of fire levels for 40 decades with fire suppression not in practice. The effects of past fire suppression are greatest in the first 10 to 15 decades. By the 40th decade, historic fire regimes are assumed to be functioning.

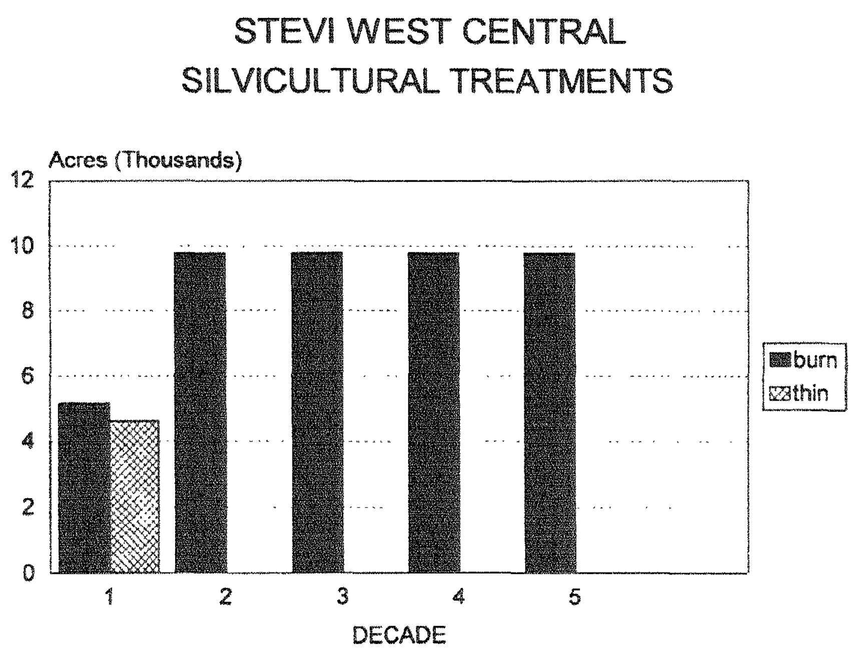


Figure 6.—Levels of silvicultural treatments applied in the ponderosa pine forest types to alter stand structure and composition. All "necessary" thinning is accomplished in the first decade. Underburning activities applied for 5 decades.

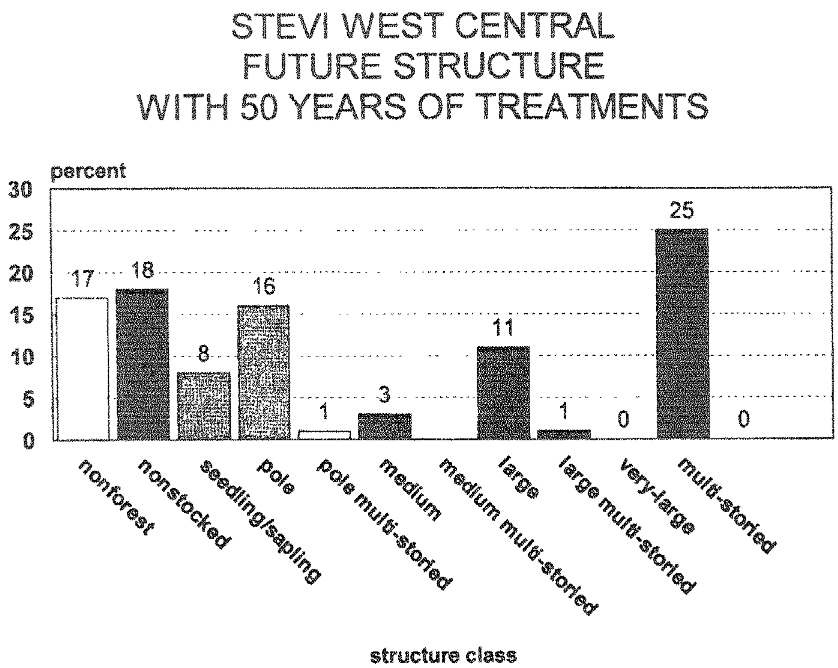


Figure 7.—Simulation of Future Condition in 50 years with the thinning and underburning activities applied.

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

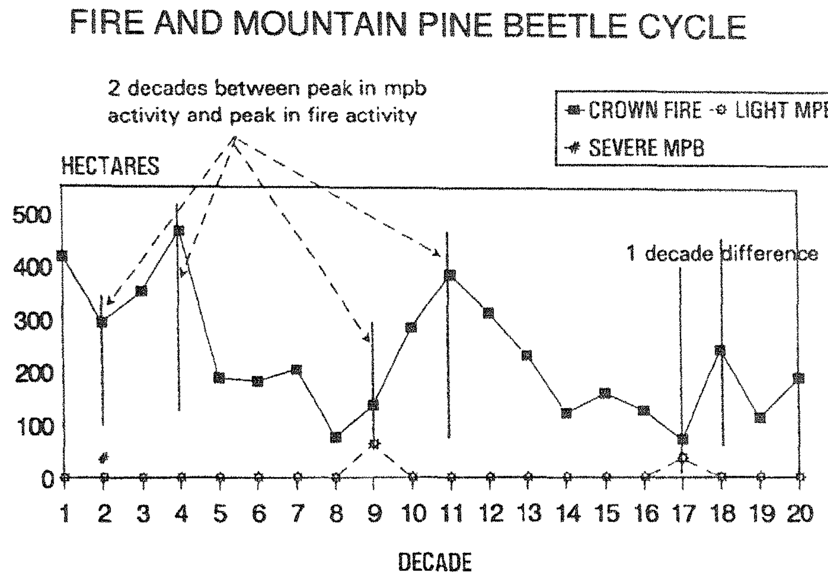


Figure 8.—Prediction of crown fire (stand replacing) and mountain pine beetle (MPB) cycles on the Coram Experimental Forest.

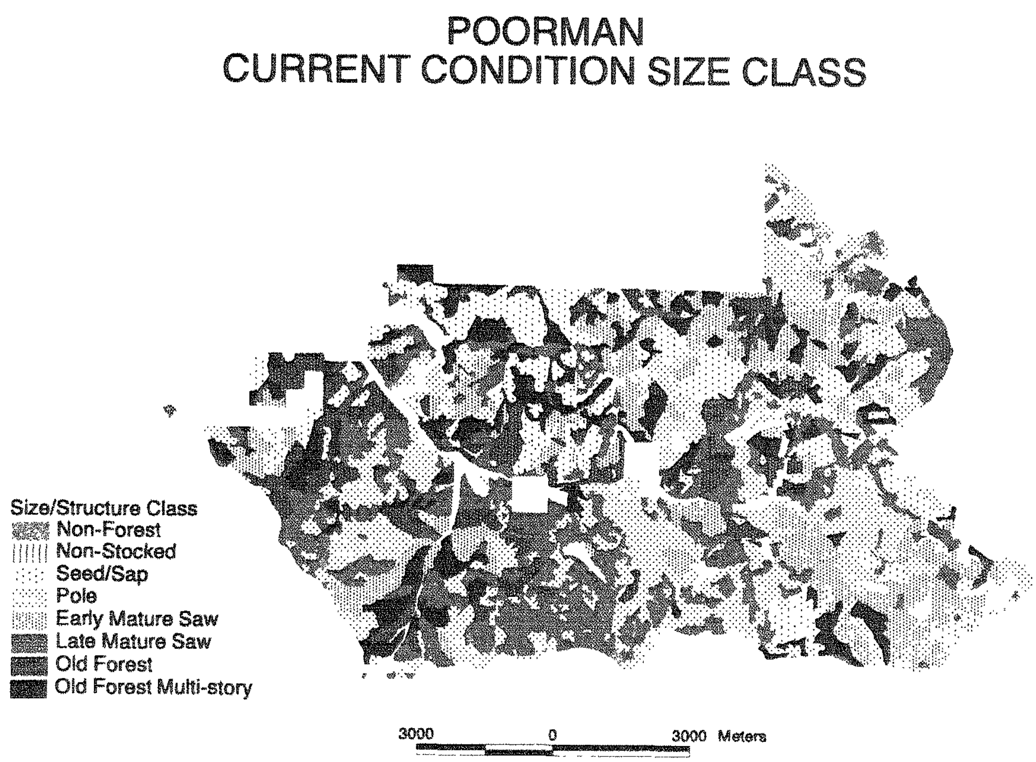


Figure 9.—Distribution of Current size and structure classes in the Poorman Project Area which is dominated by lodgepole pine. (Single story structure except as noted in legend.)

POORMAN
FUTURE CONDITION SIZE CLASS
NO TREATMENT

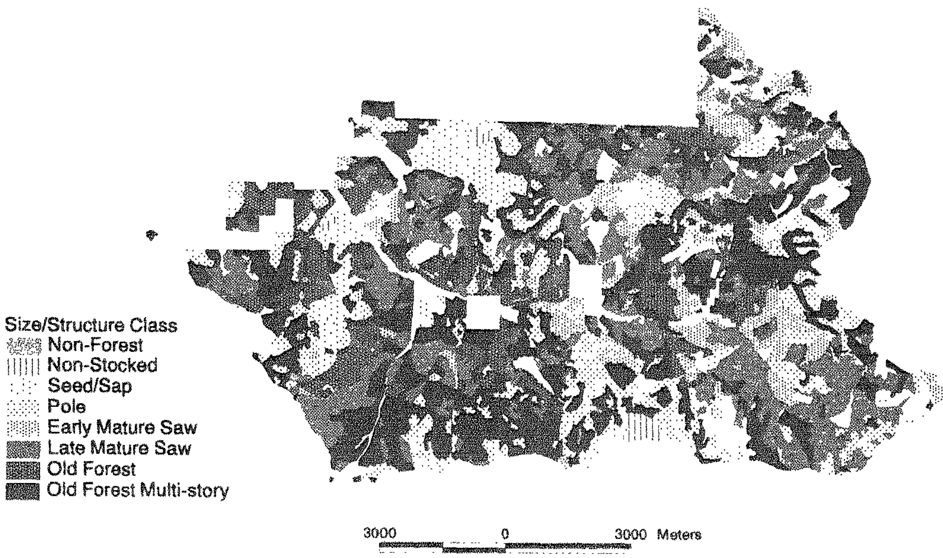


Figure 10.—Simulation of the future condition in 50 years with fire suppression being the only management activity. (Single story structure except as noted in legend.)

POORMAN
PROCESSES WITH HIGH PROBABILITY OF OCCURRENCE
IN NEXT 5 DECADES

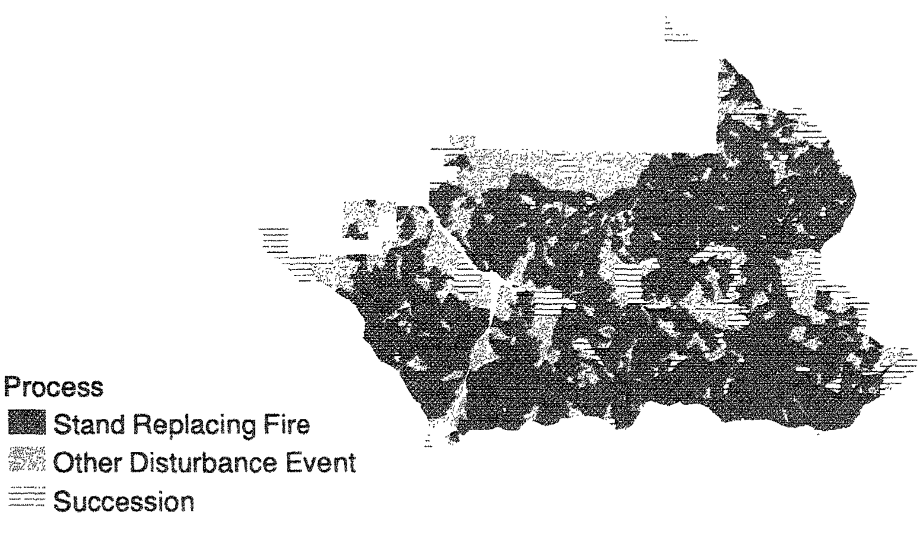


Figure 11.—Level of fire predicted over the next 50 years based on current stand conditions and fire suppression practices in place. Shaded areas represent the areas with greater than 90 percent likelihood of burning.

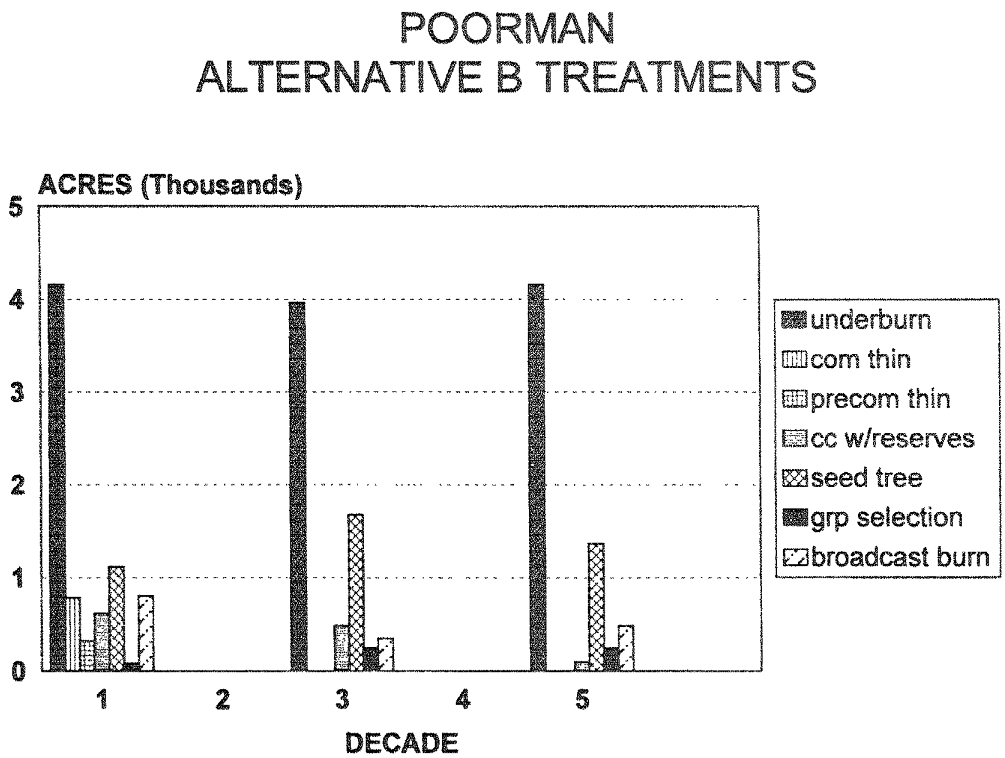


Figure 12.—Level of silvicultural treatments applied to modify stand species and size class to move towards the desired vegetative conditions. This is alternative B in the Poorman project.

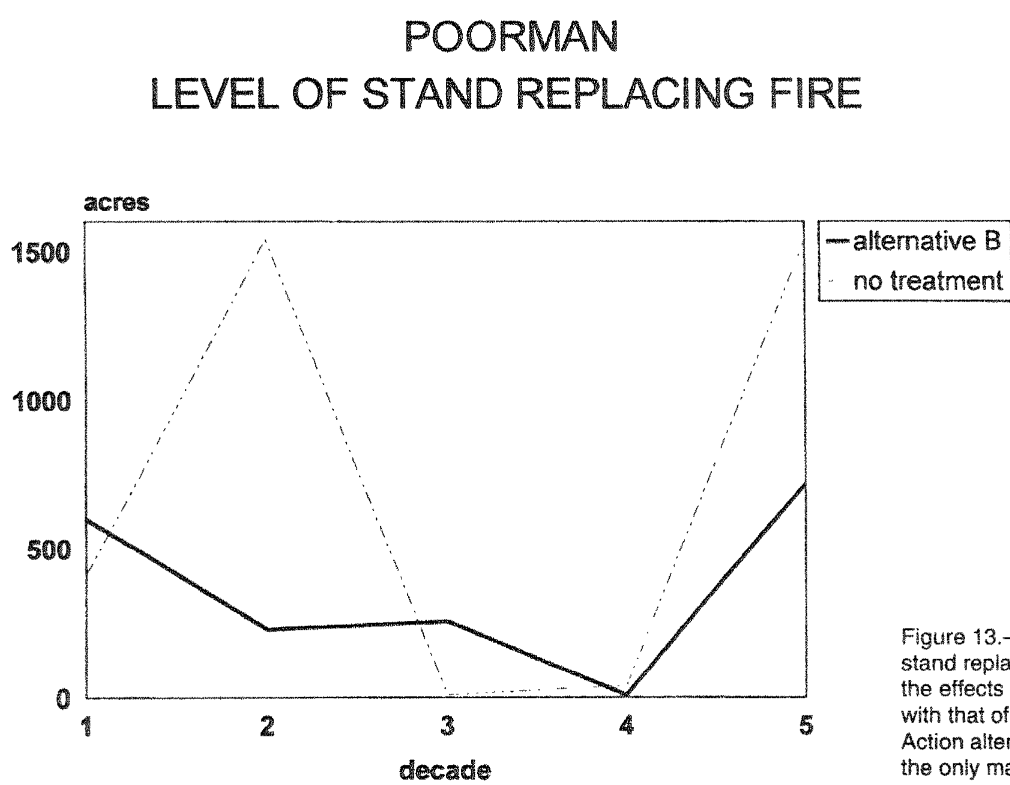


Figure 13.—Prediction of the levels of stand replacement fires comparing the effects of applying Alternative B with that of No Action. Under the No Action alternative, fire suppression is the only management activity.

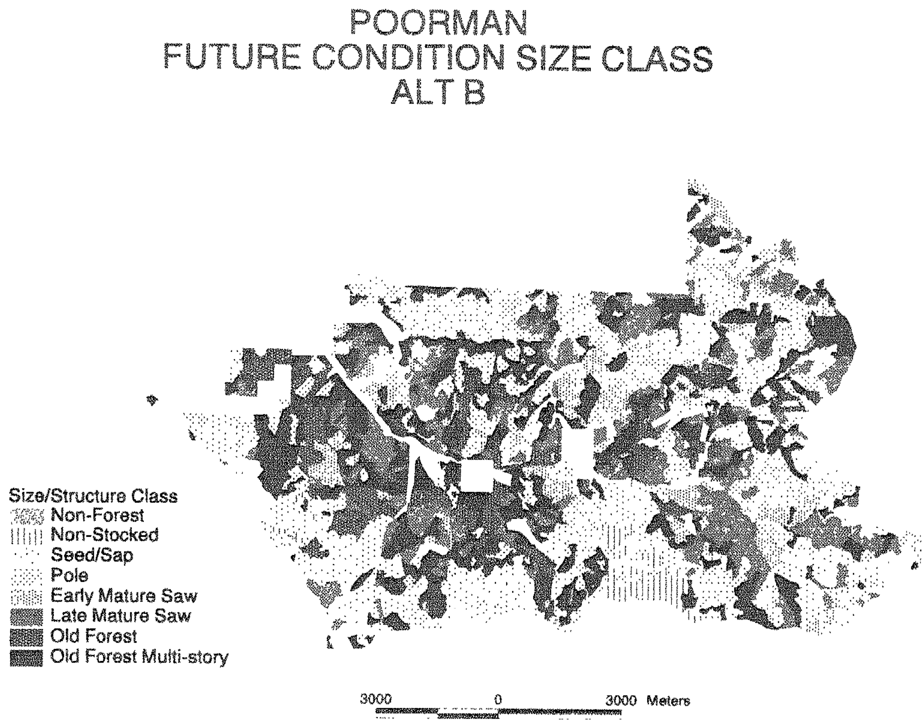


Figure 14.—Simulation of resulting Size and Structure Composition 50 years in future with the silvicultural practices applied. (Single story structure except as noted in legend.)

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.

LITERATURE CITED

Arno, Stephen F.; Reinhart, Elizabeth D.; Scott, Joe H. 1993. **Forest structure and landscape patterns in the subalpine lodgepole pine type: a procedure for quantifying past and present conditions.** General Technical Report INT-294. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest Experiment Station. 17 p.

Camp, Ann B.; Hessburg, Paul.; Everett, Richard L. 1996. **Dynamically incorporating late-successional forest in sustainable landscapes.** In: The use of fire in forest restoration. General Technical Report INT-341. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 20-23.

Gruell, George E. 1983. **Fire and vegetative trends in northern rockies: interpretations from 1871-1982 photographs.** General Technical Report INT-158. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest Experiment Station. 117 p.

Saveland, James M.; Bunting, Stephen C. 1988. **Fire effects in ponderosa pine forests.** In: Ponderosa pine: the species and its management, Symposium Proceedings. Office of Conferences and Institutes. Washington State University, Pullman: 125-131.