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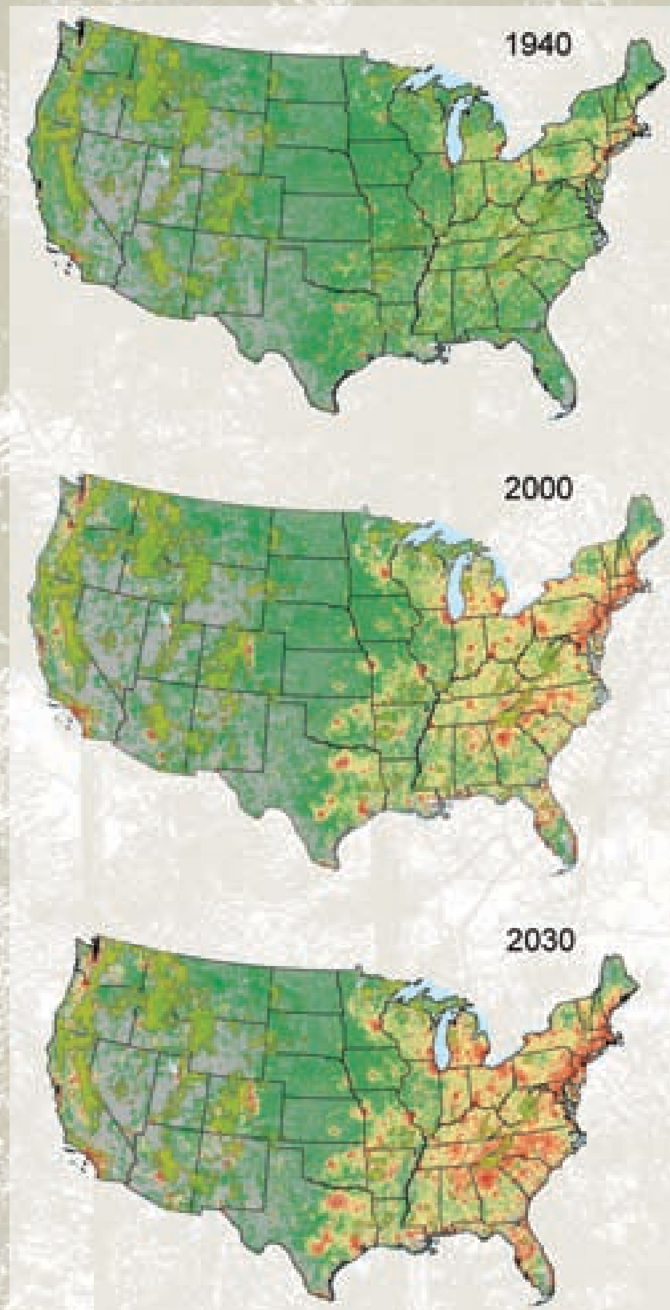

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National Perspectives on Forest Restoration

Proceedings of the 2007 National Silviculture Workshop

Caring for Our Natural Assets: An Ecosystem Services Perspective

Sally Collins and Elizabeth Larry

ABSTRACT

Global attention to climate change has advanced an awareness of human impacts on the environment. Progressing more slowly is recognition of the critical link between forest ecosystems and human welfare. Forests provide a number of societal benefits or ecosystem services, such as water purification, climate and flood regulation, recreational opportunities, and spiritual fulfillment. This paper examines an emerging perspective that describes ecosystems as natural assets that support human health and well-being. The perspective serves as both a conservation approach and an extension of ecosystem management, involving the connection of ecosystem services to the people who benefit, in some cases with an assigned market value. We argue that the emergence of an ecosystem services perspective is timely as public interest in the state of the environment increases and natural resource managers face the reality of rapid forest ecosystem change. Forest conservation that considers the supply and delivery of ecosystem services will enhance the health and resiliency of ecosystems, engage and serve a broader public, and attract private investment and leadership in a common effort to safeguard natural systems.

Keywords: ecosystem services, ecosystem management, natural capital, climate change, human well-being.

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INTRODUCTION

The City of Los Angeles was one of the first cities in the United States to address air quality concerns. Pressured by citizens to recognize the harmful health effects of smog, the city formed the Los Angeles Air Pollution Control District in 1947 and began a public campaign to control industrial emissions. In 1959, the State of California became the first state to establish air quality standards for public health (California Air Resources Board 2007). At the same time, California state legislators were refining pesticide regulations in response to an increased use of pesticides and a growing awareness of their toxicity. Just a few years later Rachel Carson completed her landmark text *Silent Spring*, exposing the environmental and human health risks of pesticides.

For many, the publication of *Silent Spring* marked the beginning of America's modern environmental movement, leading to the first Earth Day in 1970 and a series of federal regulations for environmental protection. Carson's compelling case successfully captured the attention of the American public. She instilled a broad awareness of human life as part of the natural environment, portraying both as interconnected and equally vulnerable to the side-effects of technological progress.

Today we are witnessing the stirrings of a new environmental movement related to human health and the environment. Climate change is the focus. The potential impacts of rising temperatures and sea levels around the world are stimulating public discourse and political action on a global scale; the energy around the issue reminds us of the urgency generated by *Silent Spring* and the environmental spirit that continued to shape the movement of the 1970s. Today forests are part of the conversation. Forests are a key player in climate regulation, but more notably, forests have become a symbol of popular environmentalism and sustainability, their image displayed in part on any "green" corporate strategy or "environmentally friendly" product.

The climate change issue will continue to mobilize forest awareness and conservation efforts across the globe. As society begins to internalize the costs of unsustainable development into the future, natural resource managers have a story to tell–a story about managing and investing in forests for the continued supply and delivery of ecosystem services.

Indeed, forests as healthy, functioning ecosystems support life and human welfare, providing important services in addition to storing carbon, such as water purification, erosion control, natural hazard regulation, and spiritual and cultural fulfillment.[1]

It is this critical relationship between forests and people that can lead natural resource managers to a conservation approach or perspective that is inherently tied to the dynamic needs of society. An ecosystem services perspective involves measuring the flow of ecosystem services across a landscape and connecting these services to the people who benefit. The approach is forward looking, as conservation and restoration objectives focus on the ability of ecosystems to adapt to change and to continue to supply benefits. It helps forest management remain relevant in a time of growing concern about environmental change; forest management that considers water quality, carbon sequestration, ecotourism, bioenergy, and other benefits engages and serves a broad public. Finally, an ecosystem services perspective involves the private sector in finding ways to value and conserve ecosystems. The emergence of markets for new environmental assets, for example, presents financial opportunities for working forests that extend beyond traditional forest products. Market-based approaches to conservation have the potential to provide landowners with additional incentives to manage and continue owning forest land.

[1] Ecosystem services are commonly defined as the benefits people obtain from ecosystems. A review of the definition and its history is offered by the Millennium Ecosystem Assessment (2003) and Mooney and Ehrlich (1997).

ECOSYSTEM CHANGE AND THE LOSS OF SERVICES

For the City of Los Angeles and for Rachel Carson, the sources and impacts of smog and pesticides seemed clear and the solutions straightforward: regulated behavior would ameliorate human health effects. Today we are aware of a much more complicated picture of ecosystem change, a global network of interrelated drivers peppered with uncertainty (fig. 1).

Climate scientists agree that human activities have led to elevated atmospheric concentrations of carbon dioxide and other greenhouse gases that cause global warming, and observed concentrations are projected to increase (IPCC 2007b). Why such concern? Climate change can intensify the risk of abrupt ecosystem change for terrestrial and marine systems, affecting ecosystem structure, function, and productivity. Such change will substantially impact freshwater resources, food supplies, biodiversity, and other ecosystem services at significant social and economic cost (IPCC 2007a, MA 2005, Stern 2006).

Regional climate changes and climate variations over the past century have already had a measurable impact on our natural systems, including changes in hydrology, species distribution and range, population sizes, the timing of life cycle events, and, especially in forest systems, an increase in the frequency of fire as well as pest and disease outbreaks (Brown et al. 2004; IPCC 2007a; Logan and Powell, in press; MA 2005). Globalization and associated changes in trade patterns have contributed to some of these trends, particularly through the spread of invasive species, as have past land management practices, which have contributed to forest health problems related to fire and fuels.

Land use change is an immediate issue throughout the United States, which is experiencing a loss of privately owned forest land owing to conversion to developed uses. Over 11 percent–approximately 44.2 million acres (17.9 million hectares)–of the Nation's private forests are likely to see dramatic increases in housing development by 2030 (Stein et al. 2005). This projection doesn't take into account the already fragmented woodlots in and around urban areas that are subject to local development pressures as cities expand. Indeed, urban land in the contiguous United States is expected to nearly triple over the next several decades, an increase in area larger than the state of Montana (Nowak and Walton 2005). Housing growth is also a key concern across the rural landscape, where rural sprawl or exurban development affects a much larger area, amplifying environmental impacts (Radeloff et al. 2005) (fig. 2). Expanding urbanization and rural sprawl affect the Nation's private forests, which compose nearly three-fifths of all forest land, as well as public lands and public land management. Forest-land conversion is a conservation challenge across a mixed-ownership landscape, impacting water quality, wildlife diversity, forest health, recreational access, and the many other benefits of open space.

The trends are complicated by their interaction at multiple temporal and spatial scales: changes in climate can affect land cover and use, for example, and changes in land cover and use will, in turn, affect climate variability (Loveland et al. 2003). It is clear, however, that, together and individually, these drivers of ecosystem change directly affect the supply and delivery of ecosystem services to the United States population and the international community. When forest land is developed or degraded we lose a range of goods and services provided, further increasing pressures on preserved areas to deliver the benefits lost.

AN ECOSYSTEM SERVICES PERSPECTIVE

As population, income, and consumption levels increase, humans put more and more pressure on the natural environment. In 2005, the United Nations commissioned a study of the extent to which human activities have altered ecosystems around the globe. Known as the Millennium Ecosystem Assessment (MA), the study catalogued and evaluated the status of a range of ecosystem services (fig. 3). The MA framework includes the most basic services from nature—provisioning services like the delivery of food, fresh water, wood and fiber, and medicine—and services that are less tangible and harder to measure but equally as critical, such as regulating, supporting, and cultural services. The MA scientists found that 60 percent of the world's ecosystem services are currently being degraded or used unsustainably; 70 percent of the regulating and cultural services evaluated in the assessment are in decline. The assessment predicts that the degradation of ecosystem services might significantly worsen during the first half of this century, substantially affecting human well-being.

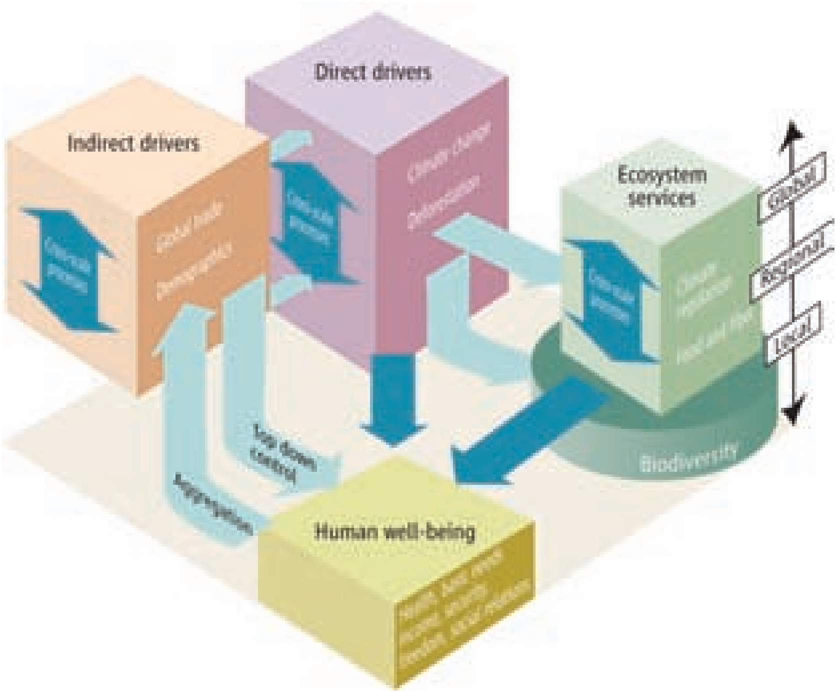

Figure 1—A conceptual framework of interactions between biodiversity, ecosystem services, human well-being, and drivers of change (MA 2005), modified by Carpenter et al. (2006) to illustrate connections among local, regional, and global scales.

ECOSYSTEM SERVICES	
Supporting Services Nutrient cycling Soil formation Primary production	**Provisioning Services** Food (crops, livestock, wild foods, etc…) Fiber (timber, cotton/hemp/silk, wood fuel) Genetic resources Biochemicals, natural medicines, pharmaceuticals Fresh water
	Regulating Services Air quality regulation Climate regulation (global, regional, and local) Water regulation Erosion regulation Water purification and waste treatment Disease regulation Pest regulation Pollination Natural hazard regulation
	Cultural Services Aesthetic values Spiritual and religious values Recreation and ecotourism

Figure 3—Ecosystem services classified by the Millennium Ecosystem Assessment (2005). The assessment evaluated the global status of provisioning, regulating, and cultural services.

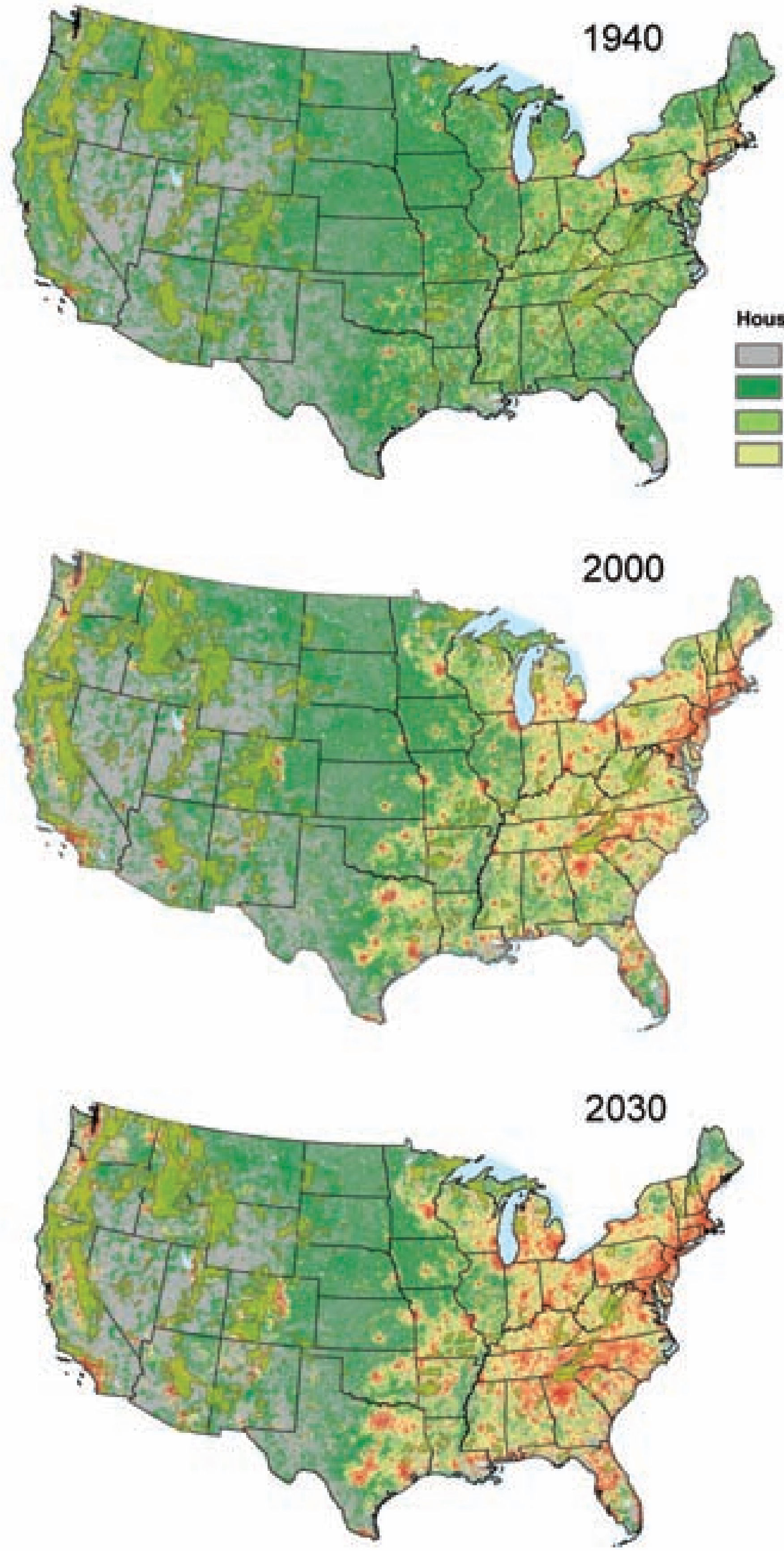

Figure 2–Housing density in the contiguous United States in 1940 and 2000, and housing density projection for 2030. Projection assumes that housing growth rates observed during the 1990s will continue without change. Units of analysis are partial block groups, a subcounty, custom division of the Census Bureau's block groups developed for this research. Provided by the U.S. Forest Service Northern Research Station and the University of Wisconsin-Madison.

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The MA framework (2003) provides a new lens through which to check the state of the environment, one that rests on "human livelihoods, health, and local and national economies" (p. 49). The findings raise important questions for natural resource managers: **Are we adequately conserving the world's ecosystems? How can we keep pace with the growing pressures of human populations? How can forest management secure ecosystem services into the future?** We have moved into a new century with a set of conservation challenges that together seem unprecedented. We need to enhance our ecosystem management approach accordingly, with a new logic and a fresh, forward-looking perspective that can meet these challenges.

Interpretations of ecosystem management evolved throughout the early to mid-1990s in response to a continuing loss of biodiversity (Grumbine 1994). For national forest managers, ecosystem management emerged as a new approach to multiple-use, sustained-yield management that incorporated the public's changing desires and needs. Resting on the concept of sustainability, ecosystem management is described as the optimum integration of human needs and requirements, the ecological potential of a landscape, and economic and technical considerations (Jensen and Everett 1994, Zonneveld 1988). The main principle, then, is to sustain the integrity of ecosystems (i.e., ecosystem functions, composition, and structure) for future generations while providing immediate goods and services to an increasingly diverse public (Jensen and Everett 1994, Overbay 1992).

Grumbine (1994: 34) argued that ecosystem management is an early stage in a fundamental reframing of the role of humans in nature. How, then, does an ecosystem services perspective advance this thinking? An ecosystem services perspective encourages natural resource managers to extend the classification of "multiple uses" to include a broader array of services or values; managing for water, wildlife, timber, and recreation addresses the need to sustain "provisioning" services, but land managers are also stewards of regulating, cultural, and supporting services, all of which are critical to human health and well-being.

An ecosystem services perspective encourages natural resource managers to consider the following:

Managing natural capital

Ecosystem services make up our natural life support system and are a form of natural capital. Like financial capital, manufactured capital, and human capital, natural capital is a requisite for economic progress and human welfare (Hawken et al. 1999). Yet natural capital is usually absent from government or corporate balance sheets; in some cases, it can take the form of a liability. An ecosystem services perspective leads natural resource managers to regard landscapes as natural capital and to account for the assets they are managing. Accounting for natural assets requires measuring the stocks and flows of ecosystem services (and their indicators or appropriate surrogates) and making sure the people who rely on these assets know their value and the cost of losing them. Information relating to the status, trends, and, to the extent possible, the economic worth of ecosystem services can better inform policymakers and the public. Understanding the extent to which a forested landscape purifies the air or moderates coastal flooding, for example, can lend priority to regional investments in land management and conservation.

Urban forestry specialists have pioneered this ecosystem services approach. In urban forestry research, management, and communications, trees are regarded as natural assets that contribute to energy savings, better air and water quality, reduced stormwater runoff, local climate moderation, increased property values–even reductions in city crime and personal stress. Empowered by this information, municipalities across the country are setting tree canopy goals and investing in tree planting efforts to enhance public benefits.

Connecting ecosystem services to the people who benefit

Ecosystem management accommodates human values and uses, but management goals are structured around the protection of ecosystems. Common themes include maintaining viable populations of native species, representing native ecosystem types across their natural range of variation, and maintaining the evolutionary potential of species and ecosystems (Grumbine 1994). From an ecosystem services perspective, by contrast, management objectives are motivated by the supply and delivery of ecosystem services. Ecosystem functions are associated with a set of life-supporting services valued by humans, and management activities are designed to maintain or enhance these services. Measures of ecosystem health, then, extend beyond forest condition to incorporate the ability of an ecosystem to deliver services to a changing population.

In practice, managers first identify the ecosystem services provided by a landscape, then assess human use and dependency on these services at local, regional, and global scales (Heal et al. 2001). Key management questions driving this process are: **Who benefits from these services? Have they identified themselves as stakeholders? Are they aware of the value of these services? Are there services at risk or in decline? How can we prevent their degradation? What are the management tradeoffs?** Answering these questions across a landscape engages a broader set of disciplines, stakeholders, and decisionmakers.

Anticipating future change

Forest management traditionally assumes an historical perspective. Forestry models are based on former conditions and assumptions, and although management objectives address a desired future condition, they are often driven by past realities. The emergence of ecosystem management reflected a growing awareness of landscapes, dynamic processes, multiple objectives, and adaptive response. But the tendency to mimic historical processes and patterns remains, and management goals for healthy, functioning forests rarely incorporate change. An ecosystem services perspective leads managers to focus on a future landscape in recognition that human needs are increasing, historical patterns are being disrupted, and natural processes are challenged by climate change. Conservation aims shift to address the ability of forested landscapes to adapt to change and continue to provide ecosystem services. Within this context a "restored" ecosystem might not mirror the original landscape, but it will be a healthy, productive system capable of meeting societal needs for a broad array of ecosystem services (MA 2005).

Managing for an uncertain future is a difficult task. Resource managers and decisionmakers who take ecosystem services into account must rely on scenario building, assessments of risk and ecological tradeoffs, economic valuation, and other methods of managing uncertainty (Carpenter et al. 2006, Heal et al. 2001, MA 2005). An ecosystem services approach underscores the importance of assessing alternative management strategies and takes demographic, economic, sociopolitical, and cultural factors into account, in addition to direct drivers of ecosystem change (Carpenter et al. 2006).

Embracing a new language

Natural resource managers now have a new language to describe the benefits of forest management–a language that helps them connect a changing population to the land and the services it provides. Too often resource specialists rely on the technical language of their profession to describe their work. Technical language enhances professional credibility and enables research and application, but it can also be highly exclusive. An ecosystem services perspective moves land managers to frame a purpose that reflects a broader set of values, with greater potential to resonate with the public. It helps build bridges of understanding between different interest groups.

INVESTING IN NATURAL CAPITAL: MARKET-BASED APPROACHES TO CONSERVATION

The ecosystem services framework developed as part of the MA is effective. It explains the full extent to which people depend on healthy ecosystems—and how much they take for granted. Whereas provisioning services are valued by society–they are, for the most part, measured, counted, and fiscally inventoried–the rest are typically absent from conventional accounting. By default, regulating, supporting, and cultural services are public goods or common resources, in most cases considered free and limitless.

Without market data or evaluation in monetary terms, the contribution of these services is often misrepresented or ignored in policy formulation and decisionmaking. Measures of economic progress and wealth do not take natural assets into account, let alone the costs of environmental degradation. A devastating oil spill, for example, will increase a Nation's gross domestic product (GDP) because each of the monetary transactions involved in its cleanup equate to positive economic growth. Similarly, an increase in a developing country's agricultural exports may register as a growth in GDP, but social costs associated with the local loss of these goods are not weighed, nor is the decline in regulating and cultural services caused by the land conversion required to increase production.

Economists have long studied how to assign monetary value to public goods in an effort to account for environmental externalities. Economic approaches to valuing the environment form the backbone of any natural resource economics text-book. But nature is priceless, some say; how can we capture its full value? Nature is priceless indeed; but unless a monetary value can be assigned, the importance of flood regulation, the role of nutrient cycling, or the restorative power of a scenic vista might be lost. Without investments in natural capital, life support systems are at risk. Nowhere is this clearer than on private lands, which account for almost 60 percent of the Nation's forests and are critical to the supply of ecosystem services. Because ecosystem services aren't valued financially, private forest landowners lack many incentives and resources to consider them in land use decisions (Kline et al. 2004). The result can be poor forest management, or forest-land conversion to developed uses.

The solution is not simple or clear, nor is it immediate. To help slow the loss and degradation of ecosystem services, economic and financial motivations need to incorporate a conservation objective. New technologies and new business models are needed to help integrate environmental goals into decisionmaking. Economic norms and accounting measures must be broadened. A necessary step is to align individual incentives with the collective interest.

In response to these needs, market-based conservation attempts to capture the value of natural capital and make land stewardship profitable. Markets for ecosystem services connect natural assets to beneficiaries who are willing to pay for their stewardship. In many cases, investments in ecosystem protection are more cost-effective alternatives to building new, or improving existing infrastructure designed to meet the same societal goals.

The carbon market is one example of associating a monetary value with nature's services. Other ecosystem service markets for wetlands, water quality, endangered species habitat, ecotourism, and bioenergy are also evolving–and with them, a chance to supplement traditional forest revenues and promote sustainable management, especially when used together with other conservation tools.

Although traditional conservation approaches have brought us far in safeguarding landscapes and biodiversity, we need to look beyond our own circle to find new tools, stakeholders, and environmental leaders. An ecosystem services perspective encourages us to be creative and entrepreneurial in bringing people together to design effective solutions.

There is no better time. Growing concern about climate change is inspiring a renewed public awareness of nature and its connection to human health, an awareness characterized in part by business action and involvement. Companies are beginning to recognize the link between environmental health and their business interests; in some cases, it is their shareholders or customers who seek a corporate environmental pledge. Markets for ecosystem services have the potential to seize the enthusiasm, catalyze private investments, and organize community leadership around a shared conservation objective.

CONCLUSION

Natural resource managers have long recognized the fundamental link between nature and society. As early as 1864, George Perkins Marsh explored the causal effects of human-induced deforestation on regional climate in his seminal work, *Man and Nature*. But we haven't always articulated the returns from investing in nature's services, or the cost of losing them. We haven't explicitly served as natural asset managers. As populations develop and prosper, the full weight of human impact on Earth's resources becomes more apparent, as does the importance of managing and accounting for these resources as natural capital that supports human well-being. Connecting ecosystem services with the people who benefit can help us manage our resources more effectively and prevent their decline.

Public interest in the state of the world's resources is on the rise, and the emergence of an ecosystem services perspective could not be timelier. We have new tools for valuing ecosystems, a new language to help us impart the benefits of forest management and conservation, and, most importantly, a restored purpose for serving as nature's stewards.

background photo by James M. Guldin

Forest Service Snapshot

Ten things the U.S. Forest Service can do in the spirit of ecosystem services. Adapted from Associate Chief Collins' opening remarks at the National Silviculture Workshop in Ketchikan, Alaska (May 7, 2007)

1. Bring certainty to the ecosystem marketplace. Uniform standards, established baselines, risk mitigation, and early demonstration can accelerate and lend credibility to emerging ecosystem service markets. Our effort to help shape the 2007 Farm Bill to facilitate market-based conservation is one step in this direction.

2. Provide the most reliable and trusted information on forests for all audiences. We are helping to reconnect children to nature through education and involvement; at the same time we're informing policymakers of the positive role that forestry can play in a climate change strategy.

3. Experiment and learn on the national forests. National forest land serves as a natural laboratory for testing ideas. Demonstration projects can serve as a resource as we help private landowners benefit from market-based conservation.

4. Become market savvy. New markets for ecosystem services require an understanding of how natural assets can be enhanced through forest management. We also need to know how the demand side works–how we can attract investments in conservation and connect conservation buyers to land stewards.

5. Reduce our environmental footprint and be the environmental leader we expect others to be.

6. Lead in research that can answer critical questions about climate change and about carbon sequestration and other ecosystem services.

7. Refresh our language. Much of our vocabulary came from the production forestry era; our words often reinforce practices and a mindset that might need to evolve.

8. Rethink forest plans—what goes into them and how we consider them. Do we need to build climate change scenarios? How can we incorporate a management approach that sustains the flow of ecosystem services across the landscape?

9. Resist the impulse to jump on the ecosystem services "bandwagon" without some thinking–and resist the impulse to dismiss the ecosystem services concept as the latest in a series of attempts to redefine forestry. At the very least, we can appreciate the dialogue that the concept is stimulating.

10. Learn as much as we can. Read, share, and connect with the issues in forestry today, and consider how they relate to the agency's mission and each of our own individual programs. Learning is a key part of our work–and we have important work to do.

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REFERENCES

Brown, T.J.; Hall, B.L.; Westerling, A.L. 2004. The impact of twenty-first century climate change on wildland fire danger in the Western United States: an applications perspective. Climatic Change. 62(1): 365-388.

California Air Resources Board. 2007. California's air quality history key events. http://www.arb.ca.gov/html/brochure/history.htm. (April 23, 2007).

Carpenter, S.R.; DeFries, R.; Dietz, T. [et al.]. 2006. Millennium ecosystem assessment: research needs. Science. 314: 257-258.

Carson, R. 1962. Silent spring. New York: Houghton Mifflin Company. 368 p.

Grumbine, R.E. 1994. What is ecosystem management? Conservation Biology. 8(1): 27-38.

Hawken, P.; Lovins A.; Lovins, L.H. 1999. Natural capitalism: creating the next industrial revolution. New York: Little, Brown and Company. 396 p.

Heal, G.; Daily G.C.; Ehrlich, P.R. [et al.]. 2001. Protecting natural capital through ecosystem service districts. Stanford Environmental Law Journal. 20: 333-364.

Intergovernmental Panel on Climate Change [IPCC]. 2007a. Climate change 2007: climate change impacts, adaptation and vulnerability. Contribution of Working Group II to the fourth assessment report of the Intergovernmental Panel on Climate Change: summary for policymakers. Geneva, Switzerland: IPCC Secretariat. 22 p.

Intergovernmental Panel on Climate Change [IPCC]. 2007b. Climate change 2007: the physical science basis. Contribution of Working Group I to the fourth assessment report of the Intergovernmental Panel on Climate Change: summary for policymakers. Geneva, Switzerland: IPCC Secretariat. 18 p.

Jensen, M.E.; Everett, R. 1994. An overview of ecosystem management principles. In: Jensen, M.E., Bourgeron, P.S., tech. eds. Volume II: Ecosystem management: principles and applications. Gen. Tech. Rep. PNW-GTR-318. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 376 p.

Kline, J.D.; Alig, R.J.; Garber-Yonts, B. 2004. Forestland social values and open space preservation. Journal of Forestry. 102(8): 39-45.

Logan, J.A.; Powell, J.A. [In press]. Ecological consequences of climate change altered forest insect disturbance regimes. In: Wagner, F.H., ed. Climate change in western North America: evidence and environmental effects. Salt Lake City, UT: Utah University Press

Loveland, T.; Gutman, G.; Buford, M. [et al.]. 2003. Land use and land cover change. In: The U.S. Climate Change Science Program: vision for the program and highlights of the scientific strategic plan. Washington, DC: U.S. Climate Change Science Program. http://www.climatescience.gov/Library/stratplan2003/final/ccspstratplan2003-chap6.htm. (August 22, 2007).

Marsh, J.P. 1864 [reprinted 2003]. Man and nature: or, physical geography as modified by human action. Lowenenthal, D., ed. Weyerhauser Environmental Classics Series. Seattle and London: University of Washington Press. 472 p.

Millennium Ecosystem Assessment [MA]. 2003. Ecosystems and human well-being: a framework for assessment. Washington, DC: Island Press. 212 p. http://www.millenniumassessment.org. (August 22, 2007).

Millennium Ecosystem Assessment [MA]. 2005. Ecosystems and human well-being: synthesis. Washington, DC: Island Press. 137 p. http://www.millenniumassessment.org. (August 22, 2007).

Mooney, H.A.; Ehrlich, P.R. 1997. Ecosystem services: a fragmentary history. In: Daily, G.C., ed. Nature's services: societal dependence on natural ecosystems. Washington, DC: Island Press. 392 p.

Nowak, D.J.; Walton, J.T. 2005. Projected urban growth (2000-2050) and its estimated impact on the US forest resource. Journal of Forestry. 103(8): 377-382.

Overbay, J.C. 1992. Ecosystem management. In: Proceedings of the national workshop: taking an ecological approach to management. WO-WSA-3. Washington, DC: U.S. Department of Agriculture, Forest Service, Watershed and Air Management: 3-15.

Radeloff, V.C.; Hammer, R.B.; Stewart, S.I. 2005. Rural and suburban sprawl in the U.S. Midwest from 1940 to 2000 and its relation to forest fragmentation. Conservation Biology. 19(3): 793-805.

Stein, S.M.; McRoberts, R.E.; Alig, R.J. [et al.]. 2005. Forests on the edge: housing development on America's private forests. Gen. Tech. Rep. PNW-GTR-636. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 16 p. http://www.fs.fed.us/projects/fote/. (August 22, 2007).

Stern, N. 2006. The economics of climate change: the Stern review. Cambridge, MA: Cambridge University Press. 712 p.

Zonneveld, I.S. 1988. Basic principles of land evaluation using vegetation and other land attributes. In: Kuchler A.W.; Zonneveld, I.S., eds. Vegetation mapping. Dordrecht, Netherlands: Kluwer Academic Publishers: 499-517.

A Framework for Restoration in the National Forests

Thomas R. Crow

ABSTRACT

Ecosystem restoration is an overarching and unifying theme for many Forest Service programs, e.g., invasive species; recovery from fire, hurricanes and other catastrophic disturbances; wildlife and fish habitat improvement. Yet the agency lacks consistent policies, definitions, and procedures regarding restoration. To address this need, a restoration framework was created. Two fundamental principles pervade the framework: (1) because restoration needs reflect diverse public values and transcend property boundaries, ecosystem restoration is based upon collaboration with the public and our partners; (2) scientific knowledge is essential to effect ecosystem restoration and necessarily serves as its basis. Although there are many definitions of restoration, no single definition fully captures the concept. To supplement a definition, the framework team drafted guiding or operational principles that stress the dynamic or changing nature of ecosystems and stress the importance of considering restoration at both local and landscape levels. The science and practices of restoration are moving away from looking backward to looking forward. What conditions do we want for the future? Applications are also moving away from creating previous states and moving toward restoring ecological processes that create healthy, productive, and diverse ecosystems. These trends support the mission of the Forest Service.

Keywords: ecosystem, Forest Service, policy, restoration, science, sustainability

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INTRODUCTION

Ecosystem restoration is an overarching and unifying management objective for many Forest Services activities (Bosworth and Brown 2007). It is integral to dealing with invasive species where they threaten native biodiversity. Recovery from catastrophic fire and major disturbances such as wind or ice storms involve restoration. Projects that improve wildlife and fish habitat are restoration projects. In fact, almost any project that is conducted on-the-ground can involve restoration in part or as a whole.

The importance of restoration to a resource management agency such as the Forest Service is reflected in recent public statements by its leaders. In a September 2006 interview published in the Summit Daily News in Colorado, Chief Dale Bosworth noted that "restoration and recreation have replaced timber harvesting as the defining activity of the agency." Likewise, he cited ecosystem restoration in an April 2006 Earth Day speech entitled In the Spirit of Earth Day: Connecting People to the Land presented at the University of California, Berkeley. In the speech, Bosworth said:

"Our focus today is on restoring and maintaining the ability of ecosystems to furnish services that people want and need. We are restoring ecosystems of all kinds, from damaged salmon and trout streams, to upland meadows and tallgrass prairies, to rangelands choked by invasive weeds, to wetlands along streams and lakes, to degraded pine and oak savannas and woodlands. Where ecosystems are in trouble, our role is to restore them to health."

In addition to public statements made by agency leaders, the role of restoration is defined by various legislative and administrative initiatives. The National Fire Plan is one such example. It was introduced in August 2000 as a joint Departments of Agriculture and Interior response to severe fire seasons with the intent of providing essential technical and financial resources to support wildland fire management across the United States. One provision of the Plan is to conduct emergency stabilization and rehabilitation activities on landscapes and communities affected by wildland fire. Explicitly recognized as part of these emergency stabilization and rehabilitation activities are "fish and wildlife habitat restoration, invasive plant treatments, and replanting and reseeding with native or other desirable vegetation."

The Healthy Forests Initiative (HFI) was initiated by President Bush in August 2002 in order to reduce the risks to people, their communities, and the ecosystems on which they depend from catastrophic fires. Much of the focus in the HFI is directed toward removing hazardous fuels through mechanical thinning and prescribed fire. Many of these activities can be considered restoration. The legislative complement to the HFI is the Healthy Forests Restoration Act of 2003 in which the word "restoration" is explicitly recognized in the title and where a section of the legislation deals specifically with protecting, restoring, and enhancing forest ecosystem components.

If the Chief's comment "we are restoring ecosystems of all kinds" is correct, then many managers in the Forest Service must be practicing restorationists. Any activity that is aimed at improving forest health or enhancing native biodiversity or improving terrestrial or aquatic habitat can be arguably called restoration. But despite the aforementioned legislative and the many administrative initiatives and despite a history of practical experience, many questions remain about the concept and the practice of restoration (Wagner et al. 2000, Harris et al. 2006). If you have a conversation about restoration with a resource manager, you are likely to hear: Exactly what do we mean by restoration? Restore to what? What does restoration mean in light of global climate change? How is success defined with restoration projects? What is the balance between rebuilding past systems and attempting to create resilient systems for the future? How are the stakeholders identified and how do we involve them in restoration activities? Does the public support restoration?

These and related questions prompted the Forest Service to charter a Restoration Framework Team to provide recommendations for improving the agency's ability to restore ecosystems on the national forests and grasslands and to provide a cohesive set of policies, definitions, and guidelines for restoration that can be applied at the national level. The purpose of this paper is to explore the commonly asked questions using the experience of the Framework Team and their recommendations provided in their January 2006 document Ecosystem Restoration: A Framework for Restoring and Maintaining the National Forests and Grasslands.

THE DEFINITION PROBLEM

The first challenge when considering the concept of restoration is to define it. For starters, The *American Heritage Dictionary* defines the word "restoration" as "the act of putting someone or something back into a prior position, place, or condition." This concept of returning to a prior condition causes an endless discussion about the legitimacy much less our ability to restore dynamic systems to a prior state in a changing world. Among the many definitions that are available in the literature, perhaps the most widely accepted is that provided by the Society for Ecological Restoration – restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed (www.ser.org). Here the emphasis is placed on the recovery of an ecosystem without stating explicitly what is being recovered (i.e., composition, structure, function), what benchmarks should be used, or what the endpoint could or should be. It is worth noting, however, that in the recent scientific literature there is a trend towards emphasizing the restoration of ecological processes that produce healthy ecosystems as opposed to recreating previous states as measured by composition (Ehrenfeld 2000). The Society for Ecological Restoration's definition also contains some value-laden terms – degraded, damaged, or destroyed – that cause concern among many managers. These terms are often viewed as indictments of past management practices. Alternative language such as "transformed" has been suggested, but each change brings new ambiguities.

It is perhaps naive to think that a single definition can fully capture a complex concept such as ecological restoration. After a survey of published definitions, members of the Restoration Framework Team decided to describe the concept through a set of guiding principles (Table 1). They amount to a mix of operational and defining principles that recognize ecosystems as dynamic and changing systems in which ecosystem processes are emphasized with realistic goals that have public support. In total, these "principles" provide a more complete picture of what restoration means to a resource management agency such as the Forest Service.

RETURNING TO THE FUTURE

The frequently asked question – restore to what? – begs another question. What is an appropriate reference condition or benchmark for ecosystem restoration? Several approaches have been used. A common benchmark is to use the historic range of variation to define the "boundary conditions" for restoring ecosystem composition and structure (Landres et al. 1999). So-called "natural areas" such as botanical areas, wilderness areas, and Research Natural Areas can serve as useful baselines to guide restoration of similar but damaged ecosystems. There are concerns related with both approaches. Among these are:

- Reference conditions are not always available.
- Reference conditions stress a single point in time (static vs. dynamic systems).
- Both approaches emphasize returning to the past as the term "restoration' suggests as opposed to managing for the future.

Table 1. The top 10 principles for implementing restoration projects (adapted from the Ecosystem Restoration: A Framework for Restoring and Maintaining the National Forests and Grasslands).

1. Seek and set goals for restoration that reflect societal choices through public involvement.
2. Make operational decisions at the lowest levels in the organization.
3. Consider restoration at multiple spatial scales.
4. Stress restoring ecosystem processes that create healthy ecosystems.
5. Establish restoration objectives and measure responses for the long term.
6. Recognize that ecosystems are dynamic and that change is inevitable; avoid "static endpoint thinking.
7. Use multiple sources of relevant information, such as historical records, scientific studies, practical experience, and indigenous knowledge.
8. Deal with uncertainty by using adaptive approaches to restoration and expect adjustments.
9. Design and implement monitoring as part of restoration.
10. Be humble and learn as you go.

- The concept of historic range of variation is too poorly defined or understood in most cases to provide useful guidance for applications.
- Past conditions may not be the appropriate endpoint for restoration but other endpoints might be more appropriate given climate change, species extirpation, invasive species, and social or economic factors such as patterns of land ownership or wildland-urban interface concerns.

When reference conditions are available, they provide valuable information about the magnitude and rate of change in ecosystem properties that may be useful in guiding restoration activities in similar but damaged ecosystems. Even so, recovering the full complement of components and functions from previous states is rarely possible due to the changing climate, altered disturbance regimes, species extirpation, and invasives.

MOVING FORWARD THROUGH RESTORATION

In his book ***1491: New Revelations of the Americas Before Columbus***, Charles Mann (2005) argues that indigenous people in the Americas were here far longer, in much greater numbers, and created far more complex and advanced societies than is suggested in many of our history books. The impacts of their collective interventions on the landscape in the "New World" were both extensive, and in some locations, intensive. In reality, people have managed the American landscape, both North and South, for thousands of years. Mann writes:

"Native Americans ran the continent as they saw fit. Modern nations must do the same. If they want to return as much of the landscape as possible to its state in 1491, they will have to create the world's largest gardens. Gardens are fashioned for many purposes with many different tools, but all are collaborations with natural forces. Rarely do their makers claim to be restoring or rebuilding anything from the past; and they are never in full control of the results. Instead, using the best tools they have and all the knowledge that they can gather, they work to create future environments."

The science of restoration is moving toward restoring ecosystem processes that create diverse, productive, and above all, healthy forest, grassland, and aquatic ecosystems (see for example, Covington et al. 1997, Allen et al. 2002). This emphasis is consistent with the Forest Service's mission "to sustain the health, diversity, and productivity of the Nation's forests and grasslands to meet the needs of present and future generations." By combining this forward looking view of restoration with an emphasis on sustaining ecosystems and the social institutions they support, we are "shaping a world to live in for the future" (Mann 2005).

IS IT SCIENCE OR ART?

As mentioned in the Chief's Earth Day speech, the focus in today's Forest Service is on restoring and sustaining the ability of terrestrial and aquatic ecosystems to furnish services that people want and need. Managers in the Forest Service are, in fact, restoring ecosystems of all kinds, including rivers and streams that are losing their capacity to support salmon or trout, western grasslands choked with cheatgrass, riparian areas dominated by salt-cedar, mountain forests that are turning brown due to tree mortality caused by bark beetle epidemics. Just how good is the science to support these efforts?

A query of Forest Service research units in which the word "restoration" appears in the mission statement or a problem statement yields an impressive list (Table 2). The list covers a wide spectrum of disciplines (e.g., genetics, soils, silviculture, entomology, pathology, wildlife, fisheries, and physiology), ecosystems (e.g., western aspen, southern bottomland hardwoods, northern riparian forests, longleaf pine), and geographic locations (e.g., tropical ecosystems in Puerto Rico and Hawaii, agricultural landscapes in the Midwest). A query into the broader academic research community, other agencies, both state and federal, and with the ongoing efforts of NGO's yields an even richer assortment of research information

There are, however, some obvious gaps in this work. The perspective from the social sciences and humanities are present but have received far less attention compared to ecological considerations. In their book ***Restoring Nature, Perspectives from the Social Sciences and Humanities***, Gobster and Hull (2000) illustrate the importance of gaining public understanding, and hopefully, political support for restoration projects when a citizens group called ATLANTIC (Alliance to Let Nature Take Its Course) complained that trees were being cut and fires set in attempts to restore prairies and savannas in the Chicago metropolitan area.

What resulted was a barrage of negative headlines in area newspapers such as “Prairie People Compile Tree Hit List” or how about “Guru’s Forest Restoration Plans Read More Like Destruction.” This is not the type of publicity that makes for successful restoration efforts.

Another obvious need is for restoration research at multiple spatial scales (principle #3 in Table 1). Most of the research has focused on projects at local levels, while much less is known about their cumulative impacts at the landscape and even regional scales (Hobbs and Norton 1996). The challenges associated with large-scale restoration projects are evident when considering case studies such as attempts to improve water quality in the Chesapeake Bay (Boesch et al. 2001), to restore the Everglades in south Florida (DeAngelis et al. 1998), or to reduce the hypoxic

Table 2. A selection of ongoing Forest Service research projects addressing restoration issues.

Pacific Southwest Research Station, Institute of Pacific Island Forestry (PSW-4154, Hilo. HI)

Restoration of Ecosystem Processes: Researchers are determining how to put tropical forests back on lands that were cleared for agriculture. Contact: Christian Giardina.

Pacific Southwest Research Station, Sierra Nevada Research Center (PSW-4202, Davis, CA)

Researchers are studying techniques and approaches for maintaining and restoring biodiversity in the Sierra Nevada Mountains. Contact: Peter Stine.

Pacific Northwest Research Station, Eastside Forest Health Restoration Team, (Wenatchee, WA)

Research includes landscape assessments of key changes in ecological patterns and disturbance regimes (fire, insect, disease) in eastern Washington and Oregon forests, and work with managers to restore patterns and functionality of wildlife habitats and forest structure, both from existing conditions and after large fires. Contact: Paul Hessburg.

Pacific Northwest Research Station, Forest Genetics Team (Corvallis, OR)

The research areas include studying genetic issues associated with restoring native trees, shrubs, grasses, and forbs. Contact: Brad St. Clair.

Rocky Mountain Research Station; Ecology, Paleoecology, and Restoration of Great Basin Watersheds (RMRS-4252, Reno, NV)

Mission: Increase understanding of the effects of both long-term climate change processes and more recent natural and anthropogenic disturbances on Great Basin ecosystems and watersheds, and use this understanding to devise meaningful scenarios for their restoration and management. Contact: Robin Tausch.

Rocky Mountain Research Station, Aspen Restoration in the Western United States (RMRS-4301, Logan, UT and RMRS-4451, Fort Collins, CO)

Research from a combination of research work units is providing valuable information for restoring aspen ecosystems in the western United States. Contact: Dale Bartos.

Southern Research Station, Center for Forest Disturbance Science (SRS-4104, Athens, GA)

Research is conducted on restoring southern forest ecosystems including longleaf pine, table mountain pine, and bottomland hardwoods. Soil quality and international restoration ecology issues are also considered. Contacts: John Stanturf (bottomland hardwoods, international; Research Ecologists: Ken Outcalt (longleaf pine restoration); Tom Waldrop (table mountain pine); Mac Callaham (soil quality).

Southern Research Station, Restoring and Managing Longleaf Pine Ecosystems (SRS-4158: Auburn, AL, Clemson, SC, Pineville, LA)

Research is directed at developing reliable restoration and management systems for sustaining longleaf pine ecosystems. Investigations range from physiological processes and ecological relationships to silvicultural systems and models for individual tree and stand growth. Contacts: Kris Connor (physiology and ecology), Auburn, AL; Research Ecologist: Dale Brockway (ecology and silviculture), Auburn, AL; Research Plant Ecologist: Joan Walker (ecology), Clemson, SC; Research Plant Physiologist: Mary Anne Sword Sayer (physiology), Pineville, LA; Research Plant Physiologist: Susanna Sung (physiology), Pineville, LA; Research Forester: Dave Haywood (silviculture), Pineville, LA; Research Forester: Jeffery Goelz (modeling, biometrics, silviculture), Pineville, LA.

Southern Research Station, Center for Forested Wetlands Research (SRS-4103, Charleston, SC, Santee Experimental Forest)

Mission: To provide the ecological information necessary to manage, sustain, and restore the structure, function, and productivity of wetland-dominated forested landscapes. Contact: Carl Trettin.

Southern Research Station, Center for Bottomland Hardwoods Research (SRS-4155, Stoneville, MS)

Research includes the restoration of bottomland hardwoods in the Lower Mississippi Alluvial Valley. Contact: Ted Leininger.

Southern Research Station, National Agroforestry Center, Lincoln, NE)

Research is conducted on the effective design of riparian buffers and the transfer of technology to restore watersheds and improve water quality. Contact: Michele Schoeneberger.

Northern Research Station, Ecology and Management of Riparian/Aquatic Ecosystems (NRS-4351, Grand Rapids, MN)

Studies are conducted to understand how restoration influences nutrient and carbon processing, surface water quality, and aquatic biota in northern riparian/aquatic ecosystems. Contact: Randy Kolka.

Northern Research Station, Silviculture and Ecology of Upland Central Hardwood Forests (NRS-4154, Columbia, MO)

Restoration studies are conducted in oak and pine savannas as well as bottomland hardwood forests. Contact: Frank Thompson.

International Institute of Tropical Forestry (Rio Piedras, PR)

Research aimed at accelerating forest recovery on degraded lands and management of secondary forests is being conducted in the Caribbean region, continental areas of Latin America (particularly Brazil) as well as Africa, Australia, and Hawaii through cooperative agreements. Contact: Ariel Lugo.

zone at the outlet of the Mississippi River caused by nutrient inputs from agricultural lands in the basin (Schulte et al. 2006). This lack of knowledge about ecological processes at large spatial scales is one reason why restoration projects at the scale of the Lower Mississippi Alluvial Valley or south Florida have proven to be so challenging. Other reasons include the lack of coordinating mechanisms for working across multiple ownerships, the lack of economic incentives to engage private landowners, and inadequate funding available for restoring large areas.

There frequently is a sense of urgency relating to restoration projects because practitioners want to move quickly in order to maintain as many possible options, e.g., restoring critical habitat for a species on the brink of extinction. In these cases, the quality of the work depends on the skill of the practitioners as they rely heavily on their experience. Without question, restoration can be successful without perfect knowledge of the target ecosystem, but there is an inherent weakness to this approach. If the science is moving toward restoring ecological processes but our understanding of these processes in incomplete, how then can success be measured? Fortunately, properties associated with ecological processes such as forest health, terrestrial and aquatic productivity, or ecological diversity are things that managers and scientists have experience in assessing and interpreting. These properties are useful surrogates for the ecological processes that improve health, productivity, and diversity and success can be measured, often times, using relative measures: Is forest health as suggested by tree mortality improving? Is diversity as measured by the number of plant species increasing?

This argument for moving forward with imperfect knowledge does not diminish the need for solid scientific information. Without the fundamental understanding of processes, restoration is limited to a series of unrelated case studies and local applications rather than a more fundamental investigation of underlying principles and mechanisms that support a broader understanding (van Diggelen et al. 2001). Without this scientific underpinning, each project becomes a new and unique challenge. The question posed as the section heading – Is it a science or an art? – is, however, a false dichotomy. As with resource management in general, restoration will always rely heavily on the skill and practical experience of the practitioner as well as the fundamental science that underpins the application. Both experience and research represent invaluable sources of information for restoration (principle #7 in Table 1).

RESTORATION AND WE THE PEOPLE

In their book chapter "The Language of Nature Matters; We Need a More Public Ecology," Hull and Robertson (2000) pose the question: "Which nature should be restored?" In exploring this question, Hull and Robertson explore three commonly used terms – naturalness, health, and integrity – for addressing their question. There exists, however, a variety or perhaps infinite number of ways to define these terms and each definition reflects a set of values and norms, either explicitly or implicitly, that create confusion and controversy. The point here is that determining restoration goals and defining the desired outcomes from restoration is best resolved through social discourse and involvement. A successful restoration project requires an expanded view beyond merely applying techniques – it requires social, cultural, political, aesthetic, and moral considerations as well (Light and Higgs 1996, Higgs 1997).

CONCLUSION

If restoration is viewed as part and parcel of resource management, as I assert, then the distinction between the two becomes blurred. Clearly, resource management encompasses more than restoration, but attempts to differentiate between the two are difficult when restoration activities are embedded within the broader framework provided by resource management. The fact that the principles presented in Table 1 apply to a vast spectrum of management activities on public lands supports this argument. Further, many restoration tools, such as widely applied silviculture practices, are already available. Consider, for example, that planting of pine can be accomplished in the context of establishing industrial plantations as well as reestablishing a species eliminated through exploitive harvesting a century ago (Guldin 2007). In this context, restoration involves thinking about using existing tools in new and creative ways as well as developing new tools when needed.

When making this argument, of course, the skeptic will view the restoration framework as nothing more than a ploy to repackage existing Agency programs (i.e., get the cut out) and that this is one more example of placing a new label on old behavior. Indeed, the restoration framework is nothing more than empty rhetoric unless specific operational procedures are defined and applied on-the-ground. Doing so is the challenge facing the Agency as resource managers struggle to meet increasing and often competing demands in a finite world with a changing climate.

Although it may seem counterintuitive, ecosystem restoration should be thought of as a forward-looking concept with emphasis on "shaping a world to live in for the future." Restoration is less about restoring an ecosystem to a prior condition and more about creating diverse, productive, and healthy ecosystems. This emphasis is consistent with the Agency's mission "to sustain the health, diversity, and productivity of the Nation's forests and grasslands to meet the needs of present and future generations." If these tenets are accepted, then restoration is about sustaining terrestrial, aquatic, and marine ecosystems and the social institutions they support. After all, they are inextricably linked.

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LITERATURE CITED

Allen, C.D.; Savage, M.; Falk, D.A.; Suckling, K.F.; Swetnam, T.W.; Schulke, T.; Stacey, P.B.; Morgan, P.; Hoffman, M.; Klingel, J.T. 2002. Ecological restoration of southwestern ponderosa pine ecosystems: A broad perspective. Ecological Applications 12: 1418-1433.

Boesch, D.F.; Brinsfield, R.B.; Magnien, R.E. 2001. Chesapeake Bay eutrophication, scientific understanding, ecosystem restoration, and challenges for agriculture. Journal of Environmental Quality 30: 303-320.

Bosworth, D.; Brown, H. 2007. Investing in the future: Ecological restoration and the USDA Forest Service. Journal of Forestry 105: 208-211.

Covington, W.W.; Fulé, P.Z., Moore, M.M.; Hart, S.C.; Kolb, T.E.; Mast, J.N.; Mast, N.; Sackett, S.S.; Wagner, M.R. 1997. Restoring ecosystem health in ponderosa pine forests of the Southwest. Journal of Forestry 95: 23-29.

DeAngelis, D.L.; Gross, L.J.; Huston, M.A.; Wolff, W.F.; Fleming, D.M.; Comiskey, E.J.; Sylvester, S.M. 1998. Landscape modeling for Everglades ecosystem. Ecosystems 1: 54-75.

Ehrenfeld, J.G. 2000. Defining the limits of restoration: the need for realistic goals. Restoration Ecology 8: 2-9.

Gobster, P.H.; Hull, R.B. (editors). 2000. Restoring nature, perspectives from the social sciences and humanities. Washington, DC: Island Press.

Guldin, J.M. 2007. Personal communication. Research Silviculturists, Southern Research Station, Hot Springs, AR.

Harris, J.A.; Hobbs, R.J.; Higgs, E.; Aronson. J. 2006. Ecological restoration and global climate change. Restoration Ecology 14: 170-176.

Higgs, E.S. 1997. What is good ecological restoration? Conservation Biology 11: 338-348.

Hobbs, R.J.; Norton, D.A. 1996. Towards a conceptual framework for restoration ecology. Restoration Ecology 4: 93-110.

Hull, R.B.; Robertson, D.P. 2000. The language of nature matters: we need a more public ecology, Gobster, P.H.; Hull, R.B., eds. Restoring nature, perspectives from the social sciences and humanities. Washington, DC: Island Press: 97-118.

Landres, P.B.; Morgan, P.; Swanson, G.J. 1999. Overview of the use of natural variability concepts in managing ecological systems. Ecological Applications 9: 1179-1188.

Light, A.: Higgs, E.S. 1996 The politics of ecological restoration. Environmental Ethics 18: 227-248.

Mann, C.C. 2005. 1491: New revelations of the Americas before Columbus. New York: Knopf.

Schulte, L.A.; Liebman, M.; Asbjornsen, H.; Crow, T.R. 2006. Agroecosystem restoration through strategic integration of perennials. Journal of Soil and Water Conservation 61: 165-169.

van Diggelen, R.; Grootjans, A.P.; Harris, J.A. 2001. Ecological restoration: state of the art or state of the science? Restoration Ecology 9(2): 115-118.

Wagner, M.R.; Block, W.M.; Geils, B.W.; Wenger, K.F. 2000. Restoration ecology: A new forest management paradigm or another merit badge for foresters? Journal of Forestry 98: 22-27.

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The Silviculture of Restoration: A Historical Perspective With Contemporary Application

James M. Guldin

ABSTRACT

In the southern United States, the turn of the 20th century saw the high-grading of virgin pine stands that left millions of acres of forestland in desperate condition. Some of these southern pine stands now support thriving forests whose patterns and processes resemble those extant before they were cut a century ago, but others do not. The success of this recovery in the southern pinery was based upon three primary elements. First, the silvics of the species had something to do with the success of their restoration; some of the southern pines have inherent ecological attributes that lend themselves to restoration, and others do not. Second, the plasticity of high-graded stands under the artful hand of the silviculturists of the day was instrumental in the recovery, partly because of the trees, and partly because of the silviculturists. Finally, major advances in silvicultural science provided astounding successes, and sometimes profound malpractice, in enabling or inhibiting the recovery. A qualitative and quantitative silvicultural review of that history can help modern silviculturists achieve goals of integrated restoration for multi-resource benefits on public and private lands, both regionally and nationally. Key elements for contemporary silviculturists to consider are:

1) that restoration of process drives restoration of structure;

2) that successful restoration demands that a silviculturist balance the cognitive dissonance between economics and ecology;

3) that some tools that traditionally have been associated with intensive forestry for fiber production can help restoration prescriptions succeed at functionally meaningful ecological scale;

4) that a diversity of silvicultural practices among stands across a landscape is more robust than a uniformity of practice; and

5) that restoration will be easier in some forest types than in others regardless of the silviculturist's efforts.

Keywords: restoration, silviculture, ecology, southern pines, conservation forestry

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INTRODUCTION

During the latter half of the 20th century, timber management was the primary goal of silviculture on public and private lands. Projections in the middle of the last century anticipated society's voracious demands for wood and fiber products, and as a result, foresters on both public and private lands began to develop silvicultural practices of agronomic intensity to meet the silvicultural goal of timber production (Spurr 1979). This was done with extraordinary competence; arguably, the two dominant advances in silviculture in the last half of the 20th century were the development of genetically improved planting stock for conifers and fast-growing hardwoods, and the use of chemical amendments such as herbicides and fertilizers to promote fast growth of the desired species and inhibit the growth of the herbaceous and woody species competing with those species. Furthermore, in an undesirable outcome for the profession, silviculture came to be universally associated with timber management (Guldin and Graham 2007).

A key element to success in using timber management has been the exclusion of extraneous damaging disturbance events from forests being managed for timber production. Key to that has been the control of wildfires, which raged through cutover areas and affected the rehabilitation and recovery of the high-graded stands. Professionals in the early part of the last century were keenly interested in forest protection, and considered wildfire the single greatest threat (e.g., Chapman 1942, Reynolds 1947). After World War II, with the GI Bill promoting college education, the profession of forestry grew rapidly--especially the labor force in professional and technical positions in Federal and State forestry agencies. With this expanded pool of workers, effective fire control finally became possible. And effective it was! The Smokey Bear symbol for prevention of wildfire has become one of the most recognized advertising symbols in the world, and control of fires became, and still is, the rule of the day for Federal and State forestry organizations.

The ability of cutover understocked forest stands in the South to recover was in part the result of extraordinary efforts to implement forest management, with emphasis on fire control and silvicultural interventions to manage what remained—especially during a period such as the Depression in the 1930s when funds were scarce and labor was inexpensive and readily available. For example, the roads, firelanes, and early buildings for the Crossett Experimental Forest in Ashley County, Arkansas, were built by Civil Works Administration field crews in 1934, working largely with hand tools, supported by the Department of Labor (Figure 1).

Figure 1— FS Photo 350876. Caption: "Typical 20-foot Forest Service road constructed with CWA hand labor. Road to be graveled and used for utilization of forest products as well as for protection and administration. Road #4 looking east from intersection of roads #4 and #6." 23 July 1937, Crossett Experimental Forest, Ashley County, Arkansas. (Photo courtesy of U.S. Forest Service, Southern Research Station)

But recovery was also due in part, and perhaps in large part, to the nature of the forest types that had been exploited. The species mixtures that recovered in these cutover stands depended upon several elements. First, some trees too small for commercial harvest survived the earlier cutting.

Second, the understocked conditions of cutover stands provided conditions suitable for new woody plants, either as sprouts, established seedlings and advance growth, or seed blown in by the wind, disseminated by animals, or otherwise brought to the site. Third, if all else failed, a new stand was established by artificial regeneration. Through these efforts, modified by infinite site-specific variations in local conditions, new forests became established and have developed to maturity. Today, across the South, thriving forests exist where cutover high-graded remnants were once common. There is a lesson in this restoration and recovery during the last century from which we silviculturists in the 21st century can learn.

For ecosystems adapted to fire, this recovery of forest condition toward the primary goal of timber production coupled with the control of fires in the woods created conditions resulting in the foremost management challenge in the 21st century—that of restoring fire to systems that are prone to burn. Fire-adapted ecosystems represent a confluence of vegetation attributes, site characteristics, and local climatic conditions resulting in ecological systems that will burn if a fire source is introduced to them. The increased fragmentation of the forested landscape places human society's infrastructural investments in homes, pasture, and communities at risk in a landscape adapted to fire, and forest stands managed in the absence of fire can be damaged or destroyed if fire occurs in an uncontrolled manner.

Coupled with this is the under-representation of two kinds of ecosystems on the landscape:

(1), ecosystems with large and old trees, since so few of them survived the high-grading at the turn of the last century, and

(2), fire-adapted ecosystems in which fire has been a regular component.

This creates management challenges, since many species of flora and fauna that require old burned ecosystems are also underrepresented on the landscape.

Thus, the rise of the 21st century poses a different set of challenges for silviculturists, especially on public lands but also in part on non-industrial private lands and even some industry lands—to restore underrepresented old, fire-adapted ecosystems in a landscape increasingly fragmented in ownership and condition. In the South, the keystone species for this restoration is the red-cockaded woodpecker and management of this species is an important objective on forest lands in the South. Equally important ecologically is the creation of the restored habitat that benefits not only the red-cockaded woodpecker, but also a host of flora and fauna adapted to similar habitat conditions.

The tools to achieve this restoration fall squarely in the realm of silviculture. But the success of the restoration has as much to do with the species being managed as it does with using silviculture to create conditions within which the desired species can develop. Interestingly, tools developed for timber production may be important.

To explore these questions, it may be useful to consider case studies from the southern pinery, and adapt lessons learned there to other ecosystems. A subjective case-study analysis of the silvics and silvicultural conditions of three southern pine forest types may have implications and lessons for current efforts in the silviculture of restoration generally. Why focus on the southern pines? Because southern pine-dominated forests grow rapidly, rotations and cutting cycles are short relative to other forest types in the nation; the southern pinery serves as a crucible for silvicultural innovation and the evolution of silvicultural practices in the woodbasket of the nation.

CASE STUDIES FROM THE SOUTHERN PINES

Virgin pine stands across the South were logged from the 1880s through the 1920s. That harvesting and associated disturbance, especially uncontrolled burning, left millions of acres in cutover condition if not completely denuded of trees. Three forest types were harvested with greatest intensity--the longleaf pine (***Pinus palustris*** Mill.) forests of the lower Gulf Coastal Plain, the mixed loblolly-shortleaf (***P. taeda*** L.-***P. echinata*** Mill.) pine forests of the upper Gulf Coastal Plain, and the pure shortleaf pine forests in the Ouachita and Ozark Mountains.

Stands throughout these regions were high-graded of all standing merchantable sawtimber. Cutting rules were simple—essentially, cut all pine trees to a 15-in stump, which translated to about a 12-inch d.b.h. Pines were not cut if they were culls, or below the merchantable threshold. This was the heyday of railroad logging, and the hardwoods (especially the hard hardwoods such as oaks and hickories) growing in mixture with the pines were often cut for railroad ties, cooperage, box manufacture, or use in chemical distillation. After logging, stands were understocked, with an overstory composition of cull pines and hardwoods, pines below the merchantability threshold, and great piles of logging slash. Fires caused by harvesting activities or by settlers to clear undergrowth to promote grasses for livestock were common in these stands. Few foresters believed that these forests would recover anytime in the foreseeable future.

Yet, some of these southern pine stands now support thriving forests. The recovery and management of the loblolly-shortleaf pine forests of the upper Coastal Plain is an astounding success, with some areas now supporting the South's fourth and fifth forests. Loblolly pine and slash pine (*P. elliottii* Engelm.) have been widely planted across the lower Gulf Coastal Plain, and are a mainstay of industrial timber production across the region. The recovery and management of mountain shortleaf pine has been less effective. Pure shortleaf pine-dominated stands and mixed pine-hardwood stands are widespread and have excellent growth and quality, although the recovery of a minor shortleaf pine component in upland hardwood-dominated stands is subject to debate. But unlike the other pine species in the southern forest landscape, longleaf pine has not recovered. It is now found on just a fraction of the area it occupied a century ago.

Figure 2— Well-stocked longleaf pine stand, Sam Houston Ranger District, National Forests and Grasslands of Texas. (Photo by James M. Guldin)

The difference in restorability or recoverability in the southern pines is a function of a number of interacting elements--the species composition, the silvics of the component species with respect to their ability to regenerate and to respond to release from suppression, the nature of the logging, and the accidental or deliberate treatment that followed. These three southern pine species and the habits they exhibit in their respective forest types offer an opportunity to speculate about the ease or difficulty of restoration, and to ponder the silvics and silvicultural attributes of each species in a subjective discussion of the potential to respond to restoration under silvicultural interventions of varying degrees.

LONGLEAF PINE ON THE LOWER GULF COASTAL PLAIN

The natural range of longleaf pine extends from southeastern Virginia to eastern Texas, and encompasses Coastal Plain, Piedmont, and mountain sites in pure or mixed stands (Boyer 1990). But longleaf is especially associated with lower Gulf Coastal Plain terrain, where it is a dominant species and at one time covered extensive areas in pure stands.

At maturity, longleaf pine stands compare favorably to other southern pines, especially with respect to straightness, quality of lumber, and yield of sawtimber volume (Figure 2). But of the three major southern pines, longleaf pine has fared the worst in the transition from cutover condition to contemporary status. An excellent summary of the conditions associated with longleaf pine harvest is presented in Earley (2004). For vast areas, cutover longleaf pine stands did not recover from high-grading, primarily because of the regeneration biology and dynamics of the species.

The slow initial establishment of longleaf pine and the difficulty associated with obtaining natural regeneration made the species impractical for management by the forest industry, especially for fiber production on short rotations. Similarly, the difficulty in obtaining seed for longleaf resulted in problems associated with widespread artificial regeneration relative to other species. These issues, together with the pressing need to reforest cutover sites in the west Gulf region, led managers to plant or direct-seed slash and loblolly pine across vast areas of cutover longleaf pine sites. As a result, longleaf pine has suffered dramatic reductions in area, from more than 90 million acres of original forest to barely three million acres today (Landers and others 1995). Today, pure stands of longleaf pine are restricted to small areas along the lower Gulf Coastal Plain, and on Federal lands in Texas and Louisiana.

Figure 3— Longleaf pine seedling in the grass stage amid dormant grasses. (Photo by D. Andrew Scott)

Longleaf pine may have existed in cutover areas as seedlings in the grass stage in cutover longleaf pine stands (Farrar, personal communication). Longleaf seedlings are difficult to distinguish from grasses (Figure 3); identification during the growing season essentially requires a taste test to identify the pine by its resinous flavor. The intermittent bumper crops of longleaf pine produce high densities of seedlings in clearly-defined age cohorts, an ecological regeneration dynamic of accumulating seedlings similar to that reported for oaks (Johnson and others 2002). After germination, longleaf seedlings remain in the grass stage and gradually increase in root collar diameter over time, under the influence of disturbance and surface fires. If they survive these influences and develop a sufficiently large root system, the seedlings break out of the grass stage and initiate height growth. Thus, it is possible that cutover areas of longleaf might have contained longleaf seedlings, but that those seedlings failed to develop because of the impacts of logging and foraging by feral hogs.

Restoration of longleaf today will be informed by several repositories of silvicultural knowledge. First, the superb work in development of the shelterwood method to regenerate longleaf pine by Southern Station scientists at the Escambia Experimental Forest in southern Alabama united attention to cone crops, understory vegetation control, and the earliest uses of prescribed fire (Croker and Boyer 1975, Boyer 1979). Keys to the method were retaining overstory trees capable of producing cones, to retain sufficient stocking of acceptable overstory trees to optimize seedfall, and to adequately prepare the site when seedfall was forecast. After germination and establishment, seedlings remained in the grass stage for extended periods of time. Brownspot needle blight (***Mycosphaerella dearnessii*** M.E. Barr) was found to inhibit emergence of longleaf pine seedlings from the grass stage, and fires were used to burn off the infected needles. However, the terminal bud of longleaf pine in the grass stage is resistant to mortality by fire because of the insulating nature of the bud scales and the protective needle whorl on the bud.

Secondly, the challenges of reforestation with longleaf have been met, especially in light of containerized planting stock and site preparation treatments that reduce the length of time longleaf seedlings remain in the grass stage (Barnett 2004). Like all southern pines, longleaf trees that have been suppressed but still retain some degree of apical dominance and suitable crown dimensions can respond to release from competition, even at advanced ages.

However, these excellent silvicultural tools of the trade are not sufficient to restore longleaf stands if longleaf is absent at shelterwood densities or greater in the residual stand. Research in artificial regeneration of longleaf pine has been so successful is in part because it has had to be, in order to effectively develop seedlings that can be competitive and especially that can quickly emerge from the grass stage, thereby enhancing their relative competitive status against competing vegetation.

SHORTLEAF PINE IN THE OUACHITA AND OZARK MOUNTAINS

The natural range of shortleaf pine encompasses 22 states from New York to Texas, second only to eastern white pine in the eastern United States (Little 1971). It is a species of minor and varying occurrence in most of these States, typically found with other pines. But in the Ouachita Mountains of western Arkansas and eastern Oklahoma, and in the Boston Mountains and Springfield Plateau of the Ozark Mountains in northern Arkansas and southern Missouri, shortleaf is the only naturally-occurring pine. Pine-dominated stands were and still are common in the Ouachitas and parts of the Ozarks (Figure 4).

Descriptions of presettlement conditions in the region point to a forest type that was more open than currently found, in terms of both overstory stem density and understory condition, with anecdotal comments that a person could ride a horse through the woods without losing their hat. That speaks to an openness of two kinds--an open understory condition promoting easy access for horses, and an overstory condition where low-hanging branches are uncommon or easily avoided.

The high-grading harvest of the Ouachita shortleaf is described in extraordinary detail in Smith (1986). Harvests progressed from south to north, and were conducted by running railroads along and through the long east-west valleys and ridges that characterize the region. Shortleaf pine stands came back in pure stands on south-facing Ouachita and Ozark hillsides that were initially dominated by pines, but questions persist whether shortleaf pine has returned as a minor and varying component in pine-hardwood and especially hardwood-pine stands in the Ozarks.

By and large, shortleaf pine has something of a mistaken reputation as a seed producer. It was thought to produce adequate or better seed crops on the order of every 3 to 6 years (Lawson 1990). But more recent research suggests that in the Ouachitas, adequate or better seed crops can be obtained from managed stands of shortleaf pine on the order of every other year (Wittwer and others 2003).

However, shortleaf pine has a unique attribute of seedlings relative to other southern pines first noticed by Mattoon in 1915—the seedlings, if top killed by fire, will resprout from a basal crook. The physiology of this phenomenon is not clearly understood. However, if a fire overruns a stand with shortleaf seedlings and saplings, many

Figure 4— Well-stocked shortleaf pine stand in pine-bluestem habitat restoration management area, Poteau RD, Ouachita National Forest, Scott County, Arkansas (Photo by James M. Guldin)

will resprout, and the conditions of fire scarification will promote a seedbed for new seedlings. The argument can be made that many shortleaf pine stands between 80 and 100 years old in the Ouachitas are probably of coppice origin after surface fires.

In current stands, shortleaf pine can tolerate overstocking, though at a cost of crown development. Perhaps one of the reasons why the species was thought to be a poor seed producer was based on examination of overstocked stands containing small-crowned trees in poor condition to produce an abundant cone crop. Open overstory conditions promote bigger crowns and better seedfall, and concurrently a more vigorous understory of understory flora.

Figure 5— Well-stocked uneven-aged loblolly-shortleaf pine stand, Compartment 56--Poor Farm Forestry Forty Demonstration, May 2006. Crossett Experimental Forest, Ashley County, Arkansas (Photo by Benjamin S. Glaze)

Seven decades of fire exclusion, however, in these shortleaf pine stands have had the effect of promoting persistent hardwood rootstocks of oaks and hickories. The silviculture of shortleaf pine-bluestem restoration requires the removal of this hardwood midstory to promote the desired grasses in the understory. To date, mechanical treatments and cyclic burning have not quite been sufficient to eliminate these rootstocks.

LOBLOLLY-SHORTLEAF PINE ON THE UPPER GULF COASTAL PLAIN

Loblolly pine has a broad natural range also, only slightly less broad than shortleaf pine and falling short to the extreme northeast and southwest. Throughout most of this natural range, loblolly and shortleaf pines grow together in highly productive stands (Figure 5), with loblolly dominating some mixtures and shortleaf others. The archetypal county in the US in which to show a diversity of silvicultural practices in this forest type is Ashley County, Arkansas, home to the Crossett EF. Here, both loblolly and shortleaf pine have historical prominence not just for the South, but the natural resource history of the Nation--because the first successful efforts to demonstrate forest sustainability through management of second-growth forests occurred in loblolly-shortleaf pine stands at Crossett, Arkansas and Urania, Louisiana (Chapman 1942).

Awareness of tree growth and the potential for economic management of second-growth stands occurred in this forest type for a simple reason—the growth of these pine stands is rapid, and easy to observe in a short period of time. Data show that well-mature stocked stands of loblolly-shortleaf pine exhibit average annual growth rates per acre of 3 square feet of basal area, 80-100 cubic feet of total merchantable volume, 400 fbm Doyle or 450 fbm Scribner. With such growth rates, high-quality sawtimber can be harvested in 50-60 years under conservative management approaches (Reynolds 1959, Reynolds 1969, Baker and others 1996, Guldin and Baker 1998, Guldin 2002).

Relatively good anecdotal evidence remains about the patterns of harvest in mixed loblolly-shortleaf pine stands of the upper West Gulf Coastal Plain, both from Chapman's work and because of the detailed descriptions of rehabilitation and recovery published from Forest Service research centered on the Crossett EF, which was established in 1935 (Reynolds 1942).

Interestingly, research papers and photo captions of the day refer to mixed second growth "shortleaf-loblolly" pine-hardwood type stands (e.g., Reynolds 1947), which may refer to a plurality of shortleaf pine in mixture with loblolly pine and hardwoods. Conversely, loblolly pine dominates these stands today. The difference may be due to the different regeneration dynamics of these two pines. Shortleaf, a less prolific seed producer than loblolly, resprouts if topkilled by fire as discussed above. But loblolly pines topkilled by fire will not recover. The tactic for loblolly seems to lie in that prolific annual seed crop, which drops adequate or better seedfall 4 years in 5 (Cain and Shelton 2001).

Control of competing vegetation, in this case hardwoods, was an essential element of the successful rehabilitation of cutover loblolly-shortleaf pine stands. Early in the recovery process, hardwoods were cut for chemicalwood (an early biofuel product) and as fuel for steam generation in operating sawmills; later, as herbicides came into common silvicultural use in the 1960s, a decadal herbicide treatment was employed and still is recommended in some silvicultural prescriptions (Guldin and Baker 2002).

The need for control of competing vegetation is especially important in situations where reproduction of desired species is found as seedlings, and they are in competition with other species that are not sought but whose regeneration occurs through sprout origin. In the southern pines, this is a dynamic between pine seedlings and hardwood sprouts, which enables the effective application of herbicides that control the hardwoods with minimal effect on the pines. But rather than consider this as a 'kill the hardwoods to release the pines' question, it is more properly seen in strict silvicultural semantics (though admittedly not by the public) as a 'kill the sprouts to release the seedlings' prescription.

Finally, one critical link in the ability of loblolly to recover from understocked cutover conditions was the ability of small suppressed trees with small crowns to respond to release from suppression, even at advanced ages. Standards developed at the Crossett EF suggest that a suppressed loblolly pine tree with a 20 percent live crown ratio, good apical dominance, and a diameter outside bark of 2 inches or greater at the base of the live crown can respond to release, and eventually develop into a codominant crown position (Baker and Shelton 1998).

COMMON THREADS IN THE RECOVERY OF THE SOUTHERN PINES

These three southern pine forest types have little that unites their successful recovery from high-grading at the turn of the last century, because the recovery varied tremendously from one forest type to the next. By and large, Coastal Plain loblolly-shortleaf pine stands fared the best, followed by pure shortleaf pine stands in the Ouachitas and

Table 1— A subjective assessment of the common silvical and silvicultural attributes that must be considered in the restoration of three major southern pine forest types.

Forest type	Frequency of seedfall	Seedling development without fire	Stem density after harvest, 1910-1930	Planting success in 1960?	Planting success today?
Longleaf pine, lower West Gulf Coastal Plain	Fewer than one crop per decade	Poor	Low	Poor	Good
Shortleaf pine, Ouachita-Ozark Highlands	Three crops per decade	Fair	Moderate	Fair	Good
Loblolly-shortleaf pine, upper West Gulf Coastal Plain	Eight crops per decade	Excellent	Moderate to high	Excellent	Excellent

Ozarks, with the poorest recovery found in the longleaf pine forest type in the lower Coastal Plain. It's possible to speculate about several reasons for this related to both silvics and silviculture (Table 1).

The most obvious factor is the frequency of seedfall, with recovery falling along the scalar of seedfall frequency. But there is probably a related effect with respect to fire exclusion. Because loblolly pine, the species with the most frequent seedfall, also has seedlings and saplings most at risk of mortality if topkilled by fire, the coincident effect of fire suppression with prolific seedfall had something to do with its successful recovery. Shortleaf pine, as Mattoon (1915) observed, had seedlings present as advanced growth and an ability to resprout if topkilled, as an adaptive trait to survive the frequent surface fires. As high-grading ended and unchecked fires were controlled, advance-growth shortleaf pine saplings may simply have responded to release, especially in pine-dominated stands. The last disturbance may also have hit shortleaf during a good seed year for the species. It's also easy to see why mixed hardwood-pine stands may be absent on the landscape today—with less fire, and fewer pines as advance growth, there would be less opportunity for pines to develop into the overstory if hardwoods dominate the site.

With longleaf, the story of seedfall is more complicated. The grass stage of longleaf is an adaptive strategy for frequent surface fires, but it renders the species difficult to see. In addition, intense fires will kill longleaf seedlings. It is likely that the heavier cut in longleaf stands relative to the other southern pines resulted in considerably more scarification, and seedfall would have been just about nonexistent from the few poor-crowned longleaf residuals after harvest. When fire was removed from the longleaf systems, the probability of longleaf seedlings escaping from the grass stage, especially when infected by brownspot, would have plummeted. Then too, the direct seeding technology that was developed to reforest the deforested longleaf stands relied on slash pine and loblolly pine rather than longleaf, largely because of seed availability (Derr and Mann 1971). Any longleaf seedlings that still persisted were not likely to survive the standard site preparation prescription used with direct seeding--a heavy cultivation treatment, either by disking or harrowing.

A second reason for the variation in recovery by these three southern pines is the degree to which a manageable residual stand was retained, a factor that generally paralleled that of the happenstance regeneration and the stocking of the initially cutover stands. Loblolly's ability to respond to release from suppression undoubtedly helped trees below the diameter limit to respond and eventually to dominate cutover sites. Shortleaf has a similar attribute, and the slower growth rates and smaller sizes of harvested trees in shortleaf probably contributed to retention of a manageable component of shortleaf pine in the mountains of the region after the high-grading occurred. Generally, longleaf pine stands - the most valuable of the three species for lumber at the turn of the last century, and also of great importance to the turpentine industry - were more heavily cut than stands in the other forest types, making recovery all the more difficult.

Finally, if a species cannot regenerate itself in desirable amounts relative to both quantity and distribution, planting will be required to obtain acceptable regeneration. The historical success of planting in these three southern pines is also correlated with recovery from high-grading. Loblolly pine was and is the easiest of the three to plant, and the rise of industrial forestry in the South relates directly to industry's proficiency in planting loblolly and to the success of the genetic improvement program over the 20th century for that species. Shortleaf seedlings are easy to grow in a manner similar to that of loblolly. But successful planting of shortleaf pine is limited by the rocky soils found in Ouachitas and Ozarks, where it is nearly impossible to insert a dibble into the ground. Planting success in shortleaf pine increased dramatically in the latter part of the 20th century with advances in site preparation practices, especially ripping to create a microeroded furrow into which seedlings could be planted; first-year survival improved quickly thereafter (Walker 1992). Conversely, technology for planting longleaf seedings has been more difficult to develop, and also required associated advances in site preparation methods so as to get longleaf pines out of the grass stage in a timely manner (Barnett 2004). Widespread application of this recent technology to successfully plant longleaf pine will be a key to the future recovery of the species.

DISCUSSION

The pattern of recovery of forest stands from high-grading at the turn of the 20th century has lessons for silviculturists in the 21st century. Those lessons relate to applying inventive tactics to take advantage of any unique ecological attributes of the species being managed, to practicing restoration of process in a larger rather than smaller landscape, and to adapting tools for widespread industrial reforestation to a restoration context.

Successful restoration is accomplished in one stand at a time. The first step is to secure the establishment and development of the desired species in the stand being managed. If the desired species for restoration are still present on the site, managers can encourage their development to the point of maturity, and apply reproduction cutting methods appropriate for the species being managed.

For example, if the desired species has the advance growth habit, the disturbance used to recreate the restoration (such as prescribed burning) must not kill the seedlings or saplings completely, or else the process of recruitment of advance growth must begin again. But advance growth reproduction dynamics relate closely to development of new shoots from undamaged rootstocks after the shoots have been top-killed by prescribed fire, as is the case with oaks and two of our southern pines. This requires careful attention to the balance between overstory shade and understory development. It is important in to manage overstory stocking to get enough light to the desired advance growth while not releasing competition too much. Generally speaking, the larger the advance growth at the time of regeneration, the greater is the likelihood of success. Irregular shelterwood reproduction cutting methods are ideal in this approach, and have been successfully applied for long periods of time in mixed loblolly-shortleaf pine stands in the upper West Gulf Coastal Plain (Zeide and Sharer 2000).

Operationally, reliance on advance growth is a less risky silvicultural tactic than relying on seedfall. Precise coordination of harvest operations with a bumper seed crop is difficult on Federal lands, given the multi-year timber sale contracts usually provided to logging contractors. Silviculturally, it is better to rely upon advance growth established prior to logging, and then prescribe site preparation or release treatments after the timber sales have been closed to re-establish advance growth as a uniform age cohort across the site. The alternative for natural seedfall is to prepare seedbeds for seedfall after the timber sale is completed, when the next adequate or better seed crop is expected.

Reproduction cutting methods that rely upon advance growth must be initiated well in advance of the seed cut. Advance growth of a desired species should be encouraged through silvicultural interventions as much as 2 decades prior to the reproduction cutting, so as to be in place prior to the establishment of the new stand. In pines, that can often be accomplished using prescribed fire, which acts both to control competing vegetation and to scarify the forest floor so as to promote germination and seedling establishment—a prescription shown to be effective in loblolly, longleaf, and shortleaf pine. Fire must then be excluded until the seedlings are tall enough to survive it, at which time fire can be reintroduced to the restoration prescription.

Second, some measure of overstory density reduction will be required in most restoration prescriptions, especially if stands have developed through the 20th century after a turn-of-the-century high-grading. In intolerant species, opening stands in this way promotes understory development, which places a premium on the implementation of understory treatments that encourage the desired understory species of forbs and grasses rather than a preponderance of woody plants, especially those tolerant of shade. The limits within which an acceptable understory development of desired forbs and grasses can be mated to acceptable levels of woody plant advance growth for eventual use in reproduction cutting requires a certain degree of balance. It also requires that a silviculturist has some confidence that when the time comes, the desired tree species can be developed immediately after a reproduction cutting prescription is implemented.

Thirdly, successful restoration silviculture demands that a silviculturist balance the cognitive dissonance between economics and ecology. If a reduction in overstory density is prescribed, it is certainly to the advantage of the silviculturist to do so using commercial timber sales. Appropriated funds are usually less readily available than trust funds, which are based in timber sale receipts and thus represent a more liquid capital asset. If a silviculturist can use timber sales to liquidate standing volume assets in excess to the need for restoration, monies for sale area improvement can then be collected and applied for restoration purposes through supplemental reforestation and release treatments. The bottom line is that the area that can be restored using timber sale proceeds is often much larger than can be restored with appropriated dollars. For example, suppose a restoration prescription outside a sale area costs $75 per acre to implement. If 3 mbf per acre of volume in excess of restoration needs can be harvested at $250/mbf, $750 per acre will be generated from the timber sale; conservatively, half of that could be applied for restoration prescriptions within that sale area over the next 5 to 10 years. Over a 200-acre project area in a watershed under prescription development, a manager would need $15,000 in appropriated funds to treat an area, or could draw from a pool of $75,000 in the same area from the timber sale proceeds. Applying the timber sale program in a restoration context provides substantially more flexibility in restoring a larger number of acres at less cost to the agency than would be possible using appropriated dollars, as has been shown in the pine-bluestem restoration program on the Ouachita NF (Guldin and others 2004). The key is in defining the meaning and intent of the 'standing volume in excess of restoration' concept.

Fourth, some tools such as artificial regeneration that traditionally have been associated with intensive forestry for fiber production can be important in restoration. But modification of prescriptions and recommendations may be in order. For example, tree planting will be an important tool for forest restoration when a species is absent from the stand being restored, or in species with erratic seed production. But the practice will differ from planting where industry fiber management is a goal. A new world of opportunity opens for forest geneticists in this context, because we do not know whether families selected for rapid height and volume growth in intensively site-prepared stands will be the same families that thrive in partial shade, or where site preparation is less than complete. Then, too, there may be wisdom in variations of tree spacing when planting for restoration objectives so as to create stem patterns other than rows. A planting crew can plant 544 trees per acre on a strict 8 x 10 ft spacing, or by planting trees on a 3-ft to 15-ft spacing provided that the spacing variation is calibrated to hit the mean.

Fifth, no silvicultural practice should be arbitrarily excluded from the tools in the toolbox of restoration. One tool more cussed than discussed in the 21st century is the use of herbicides, largely because of public distaste for the practice. However, in the southern pinery, herbicides are extremely effective in controlling competing vegetation, especially as a tool to kill sprouting hardwoods competing with pine seedlings or saplings. Midstory hardwoods that became established after the onset of effective fire control may not be desired in the restored stand, and are very difficult to remove without herbicides. Similarly, herbicides may be the only effective way to control invasive exotics such as kudzu and cogon grass that have invaded sites intended for restoration. Silviculturists must justify the use of herbicides for restoration based on achieving the ecological goals the restoration is designed to achieve—and even then, there might be considerable public opposition to the practice. However, in many instances, herbicides will be the single most effective and least costly treatment to control unwanted vegetation. This or any other practice should not be ruled out in advance of silvicultural planning.

However, restoring one stand does not restore the functional ecosystem attributes that transcend the scale of an individual stand. Restoration of ecosystems connotes a scale larger than a single stand, and thus the silviculture of restoration will require prescribing silvicultural treatments concurrently in many stands toward a common ecological goal. This requires that silviculturists expand their view from the traditional stand to the appropriate functional ecological scale. The resulting system of prescriptions for stands within the landscape should become, ecologically speaking, more than the sum of the stand-level prescriptions.

In this context, it is likely that diverse silvicultural practices among stands across a landscape will be more robust than a single textbook prescription. Thirty years ago in Region 8, reproduction cutting decisions invariably prescribed clearcutting and planting, which met important objectives of timber production and creation of early seral conditions, but generally did so in 30- to 40-acre blocks on the landscape. A greater diversity in size and intensity of early seral condition might have been obtained using a diverse even-aged and uneven-aged reproduction cutting methods, not just clearcutting, and through operations in stands of varied area. Similarly, contemporary silviculturists should resist the urge to employ a single restoration prescription, lest the restored conditions become too uniform and fail to reflect the range of natural variability that would be desirable in restored conditions.

Finally, restoration will be easier in some forest types than in others despite the silviculturist's best efforts. The key is the ease with which regeneration of the desired species can become established and encouraged to develop. Some species such as loblolly pine could be restored by taking advantage of that bumper seedfall four years in five, with minimal capital investment. Others such as longleaf will require widespread reforestation using artificial regeneration, with large capital investment to ensure survival. Silviculturists should be increasingly aware of the opportunities for ecological interconnectedness through complementary silvicultural operations in adjacent stands, and through operations on a broad scale rather than a narrow one. The success of restoration in the Ouachita Mountains, for example, is not so much at the scale of a 40-acre stand as at the scale of a 40,000-acre south-facing ridge. This experience exemplifies the silvicultural opportunity of the 21st century—learning how to enable restoration of landscapes through functional arrangements of stands, restored one stand at a time by a silviculturist plying a time-honored craft.

LITERATURE CITED

Baker, J.B.; Cain, M.D.; Guldin, J.M.; Murphy, P.A.; Shelton, M.G. 1996. Uneven-aged silviculture in the loblolly and shortleaf pine forest types. Gen. Tech. Rep. SO-118. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 65 p.

Baker, James B.; Shelton, Michael G. 1998. Rehabilitation of understocked loblolly-shortleaf pine stands - II. Development of intermediate and suppressed trees following release in natural stands. Southern Journal of Applied Forestry 22(1):41-46.

Barnett, James P. 2004. Restoring the longleaf pine ecosystem: The role of container seedling technology In: Shepperd, Wayne D.; Eskew, Lane G., compilers. 2004. Silviculture in special places: Proceedings of the National Silviculture Workshop; 2003 September 8-11; Granby, CO. Proceedings RMRS-P-34. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. p. 127-134.

Boyer, William D. 1979. Regenerating the Natural Longleaf Pine Forest. Journal of Forestry, Vol. 77, No. 9 September 1979.

Boyer, W.D. 1990. Longleaf pine. In: Burns, Russell M.; Honkala, Barbara H. (tech. Coords.) 1990. Silvics of North America: 1. Conifers; 2. Hardwoods Agriculture Handbook 654, U.S. Dept. of Agriculture, Forest Service, Washington, D.C. vol.2, 877 p.

Cain, Michael D.; Shelton, Michael G. 2001. Twenty years of natural loblolly and shortleaf pine seed production on the Crossett Experimental Forest in southeastern Arkansas. Southern Journal of Applied Forestry. 25:1 40-45.

Chapman, H.H. 1942. Management of loblolly pine in the pine-hardwood region in Arkansas and in Louisiana west of the Mississippi river. Bulletin #49. New Haven, CT: Yale University, School of Forestry. 150 p.

Croker, Thomas C., Jr.; Boyer, William D. 1975. Regenerating Longleaf Pine Naturally. Res. Pap. SO-105. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 26 p.

Derr, H.J.; W.F. Mann, Jr. 1971. Direct-seeding in the South. USDA Forest Service. Agriculture Handbook no. 391. 68 p.

Earley, Lawrence S. 2004. Looking for longleaf: the fall and rise of an American forest. Chapel Hill, NC: The University of North Carolina Press. 322 p.

Farrar, Robert M. Personal communication, Escambia Experimental Forest, May 1982.

Guldin James M.; Graham, Russell T. 2007. Silviculture for the 21st century—objective and subjective standards to guide successful practice. P. 109-120. In: Powers, Robert F., tech. ed. Restoring fire-adapted ecosystems: proceedings of the 2005 National Silviculture Workshop. June 6-10, 2005, Tahoe City, CA. Gen. tech. Rep. PSW-GTR-203. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 306 p.

Guldin, J.M.; Strom, J.; Montague, W.G.; Hedrick, L.D. 2004. Shortleaf pine-bluestem habitat restoration in the Interior Highlands: Implications for stand growth and regeneration, p. 182-190. In: Shepperd, W.D.; Eskew, L.D., compilers. 2004. Silviculture in special places: proceedings of the 2003 National Silviculture Workshop; 2003 September 8-12, Granby CO. Proceedings, RMRS-P-34. Ft. Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 255 p.

Guldin, J.M.; Baker, J.B. 1998. Uneven-aged silviculture, southern style. Journal of Forestry 96(7): 22-26.

Guldin, J.M. 2002. Continuous cover forestry in the United States—experience with southern pines. In: Continuous cover forestry: assessment, analysis, scenarios. von Gadow, Klaus; Nagel, Jurgen; Saborowski, Joachim (eds.). Kluwer Academic Publishers, Dordrecht, The Netherlands: 295-307.

Johnson, P. S.; Shifley, S.R.; Rogers, R. 2002. The ecology and silviculture of oaks. New York, NY: CABI Publishing. 503 p.

Landers, J. Larry; van Lear, David H.; Boyer, William D. 1995. The longleaf pine forests of the southeast: requiem or renaissance? Journal of Forestry 93(11): 39-44.

Lawson, E.R. 1990. Shortleaf pine. In: Burns, Russell M.; Honkala, Barbara H. (tech. Coords.) 1990. Silvics of North America: 1. conifers; 2. hardwoods agriculture handbook 654, U.S. Dept. of Agriculture, Forest Service, Washington, D.C. vol.2, 877 p.

Little, Elbert L., Jr. 1971. Atlas of United States trees. vol. 1. Conifers and important hardwoods. U.S. Department of Agriculture, Miscellaneous Publication 1146. Washington, DC. 9 p., 313 maps.

Mattoon, W.R. 1915. Life history of shortleaf pine. Bulletin 244. Washington, D.C.: U.S. Department of Agriculture. 46 p.

Reynolds, R.R. 1947. Management of second-growth shortleaf-loblolly pine-hardwood stands. Journal of Forestry 45(3): 181-187.

Smith, Kenneth L. 1986. Sawmill: the story of cutting the last great virgin forest east of the Rockies. Fayetteville, AR: The University of Arkansas Press. 246 p.

Spurr, S. 1979. Silviculture. Scientific American 240 (2): 76-82, 87-91.

Walker, William D. 1992. Historical perspectives on regeneration in the Ouachita and Ozark Mountains—the Ouachita National Forest, p. 12-17. In: Brissette, John C., and Barnett, James B., comps. 1992. Proceedings of the shortleaf pine regeneration workshop; 1991 October 29-31; Little Rock, AR. Gen. Tech. Rep. SO-90. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 236 p.

Wittwer, Robert F.; Shelton, Michael G.; Guldin, James M. 2003. Effect of reproduction cutting methods and hardwood retention on shortleaf pine seed production in natural stands of the Ouachita Mountains. Southern Journal of Applied Forestry 27 (3): 206-211.

Zeide, B., and D. Sharer. 2000. Good forestry at a glance: a guide for managing even-aged loblolly pine stands. Fayetteville, Arkansas: Arkansas Agricultural Experiment Station, Arkansas Forest Resources Center Series 003. 19 p.