FIRE AND SILVICULTURE

RECENT ADVANCES IN THE SILVICULTURAL USE OF PRESCRIBED FIRE

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ABSTRACT

Although the silvicultural use of prescribed fire has been researched for almost 70 years, new advances are still being made. These advances are primarily the result of (1) a better understanding of fire as an ecological process and (2) the use of this knowledge to restore declining ecosystems, save threatened and endangered species, enhance natural beauty, and regulate composition and structure of plant communities. The role of growing-season fires, avoided in the past century, in shaping the composition and structure of longleaf pine (*Pinus palustris*) ecosystems has recently been established. Silvicultural prescriptions for using prescribed fire to benefit oak (*Quercus* spp.) regeneration on good sites have been developed. Prescribed fire is being used to restore the historical character and health of ponderosa pine (*P. ponderosa*) ecosystems in the southwestern United States and to regenerate Table Mountain (*P. pungens*) and pitch pine (*P. rigida*) ecosystems in the southern Appalachian Mountains. Guidelines also have been developed for using prescribed fire to thin dense natural stands of loblolly pine (*P. taeda*). Ongoing research continues to identify new uses of prescribed fire to enable ecosystem management to become a more fully implemented paradigm in the twenty-first century.

keywords: biodiversity, ecosystem restoration, oak regeneration, prescribed burning, thinning.

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INTRODUCTION

Prescribed burning evolved from old practices such as land clearing and protective burning (Pyne et al. 1996). Traditional forestry uses include: (1) reducing fuel hazards, (2) preparing seedbeds and sites for regeneration, (3) controlling understory hardwoods, and (4) improving wildlife habitat. Prescriptions for using prescribed fire for these reasons were first developed in the southern pine forests (Wade and Lunsford 1988) and later in the coniferous forests of the Pacific Northwest (Martin 1990).

Fuel reduction and other traditional uses of prescribed fire were designed to accomplish very important but rather narrowly focused resource management objectives. These objectives have generally failed to capture the attention and hearts of the general public. Perhaps for that reason, prescribed fire has not yet garnered the public support needed to help it survive as an important forest management tool into the next century.

Though still used for these traditional reasons, prescribed fire over the last 2 decades has come to be used for other purposes as well. Researchers now understand that most of the presettlement forests of the United States had adapted to fire on a frequent or infrequent basis (Williams 1989, Agee 1993, Pyne et al. 1996). Fire can be used to accomplish broader ecological objectives, which could capture the interest and perhaps the support of the environmentally conscious public. Prescribed fire is now being used to restore and maintain valuable but declining ecosystems, to protect rare plant and animal species, to enhance natural beauty, and to promote general ecosystem health on a landscape basis.

In this paper, I will describe a few recent advances in the silvicultural use of prescribed fire, and explore the basis for these advances. My definition of silviculture is a broad one: silviculture is applied ecology, tempered by economics and social concerns, to achieve management objectives.

WHY THIS NEW INTEREST IN PRESCRIBED BURNING?

Foresters and resource managers are developing a new and broadened view of silviculture and the role of fire in ecosystem management. Early in this century, silviculture was narrowly defined as the production of wood crops (Hawley 1921). With the passing decades, more attention has focused on the ecological foundations upon which silviculture is based, and today silviculture is recognized as applied ecology (Smith et al. 1997). The increasing realization that ecosystem management in its broadest sense will be the model for forest management into the next century means that a better understanding of ecosystem processes, including fire, will be essential if we are to properly manage forest ecosystems on a landscape scale.

Though not generally appreciated, fire historically played as important a role in shaping composition and character of the landscape as the more readily accepted factors of climate, soil, topography, and time. Using prescribed fire, to the extent feasible, to simulate natural fire regimes will help maintain the health and integrity of those ecosystems where fire was a major factor. Indeed, prescribed fire is essential to maintaining the very existence of certain ecosystems.

There are increasing pressures against using fire on the landscape. These forces arise primarily from concerns about air quality-human health relationships (U.S. Environmental Protection Agency 1997, Achtemeier et al. 1999) and liability (Mobely 1989). On the other hand, the public is now beginning to understand the risks of not using fire in certain ecosystems, e.g., greater difficulty in containing wildfires, loss of species, and declining forest health.

A decade ago, I was somewhat pessimistic about the future of prescribed fire. Today its future appears brighter because of greater understanding by resource managers, as well as the general public, that prescribed fire is essential to achieve goals perceived by the public to be socially responsible. The link between managed fire and society's well-being is now more firmly established, although the need for public education in this area remains critically high.

NEW SILVICULTURAL USES OF PRESCRIBED FIRE

Almost 15 years ago, I coauthored a paper about recent advances in the silvicultural use of prescribed burning (Van Lear and Waldrop 1985). Among the advances mentioned were: (1) development of aerial ignition systems to burn large areas in a short amount of time, (2) implementation of site preparation burns in the southern Appalachian Mountains to regenerate mixed pine-hardwood stands, (3) possible use of fire to favor oak regeneration, (4) enhancement of red-cockaded woodpecker (*Picoides borealis*) habitat with understory burning, (5) development of smoke management guidelines, and (6) development of fire behavior models. Many of these sound old-hat these days, but they were new ideas in the early 1980's. Over the past 10 years, new advances in the use of prescribed fire have appeared.

Implementation of Growing Season Burns in Longleaf Pine Ecosystems

One of the major reasons for the century-long decline of the longleaf pine-wiregrass (*Aristida* spp.) ecosystem has been suppression of growing-season fires. Only in the last decade has the need for growing-season burns been appreciated (Noss 1989, Brennan et al. 1998). It is now apparent that growing-season burns are required in large part to restore the historical diversity and open structure of this aesthetically beautiful ecosystem (Noss 1989, Frost 1993, Streng et al. 1993, Landers et al. 1995). This realization is a major advance in the application of prescribed fire and represents a break from 70 years of traditional dormant-season burning.

The lagging acceptance of growing-season burning is remarkable since more is known about the role of fire in the longleaf pine-wiregrass ecosystem than in perhaps any other. As long ago as the 1930's, Stoddard (1931) did extensive research on effects of prescribed fire on the bobwhite quail (*Colinus virginianus*) and its habitat. However, despite the knowledge generated by this and dozens, if not hundreds, of other studies, the longleaf pine ecosystem has continued to decline. Today it occupies only about 3% of its presettlement extent (Frost 1993, Landers et al. 1995). As a result of the decline in longleaf pine habitat, species such as fox squirrels (*Sciurus niger*), gopher tortoises (*Gopherus polyphemus*), and red-cockaded woodpeckers, which once thrived in the relatively open habitats, are now rare, as are nearly 200 plant species that occupy this highly diverse ecosystem (Walker 1993, Brennan et al. 1999).

Growing-season burns promote flowering by many grasses and other herbaceous plants in the longleaf pine ecosystem and discourage or even eliminate the hardwood understory (Robbins and Myers 1992). Reduction in fire frequency gradually reduces or eliminates the herb layer that supports the complex web of life in longleaf pine ecosystems. Periodic winter and early spring burns were often used too infrequently to adequately control hardwood understories, resulting in conversion of millions of hectares of open longleaf pine savannah to stands with a dense scrub oak understory. In many cases, dormant-season burns were so infrequent that understory hardwoods became too large to be controlled by burning, or longleaf pines sites were invaded by other southern pines (Frost 1993, Landers et al. 1995).

Although growing-season fires mimic the natural fire season in the South and are essential in restoring the historical character of the longleaf pine ecosystem, tradition and practical considerations ensure that not all burning will be conducted in the growing season. Fortunately, dormant-season fires can be periodically interspersed within a regime of growing-season fires to restore the longleaf pine ecosystem. In fact, frequent dormant-season burns (every 2 years) carried out over a long time also can increase understory richness and enhance productivity of grasses and forbs in longleaf pine ecosystems (Brockway and Lewis 1997). A combination of dormant- and growing-season burns may be necessary to restore the diversity of the longleaf pine ecosystem (Walker 1993, Hermann et al. 1999), as well as to accomplish more traditional management objectives (Franklin 1997). Myers and Van Lear (1998) propose that opportunistic land managers can facilitate the process of restoring diverse longleaf pine ecosystems by implementing a regime of frequent prescribed fires, supplemented with planting if necessary, in forested areas impacted by strong hurricanes.

Despite a century-long decline in the areal extent of longleaf pine, we can now be optimistic about the future of the species that once was synonymous with the South. The Longleaf Pine Alliance (Kush 1996), a consortium of federal and state government agencies, large and small private landowners, conservation groups, and others, has recently embarked on a major effort to restore the longleaf pine ecosystem not only on public lands, but on private lands as well. Other partnerships, such as the Safe Harbor Program of the U.S. Fish and Wildlife Service, and citizens groups, such as the Sandhills Area Land Trust and the Coastal Carolina Conservation League, have vested interests in maintaining and restoring healthy longleaf pine ecosystems, which must translate into a greater emphasis on prescribed burning.

Prescribed Burning for Oak Regeneration

For decades, silviculturists have puzzled over the problem of securing vigorous oak regeneration on good-quality sites in the eastern United States. Mature mixed oak stands occupy many of these sites today, but attempts to regenerate them with clear-cutting or shelterwood cutting almost invariably lead to conversion to such fast-growing, shade-intolerant species as yellow poplar (*Liriodendron tulipifera*) (Loftis 1983, Lorimer 1993). Using fire in hardwood stands has not been considered feasible because of the widely recognized damage to boles of overstory trees from wildfires, and more recent accounts of bole damage from prescribed fires (Wendell and Smith 1986). However, in developing silvicultural prescriptions whose objective is to maintain or restore ecosystems, we should look first at the disturbance history that maintained that ecosystem. Then we can learn to mimic that disturbance regime with minimal financial impact.

Although many people have suggested that prescribed fire may be useful in regenerating oaks, no silvicultural prescriptions to accomplish this goal had been developed or tested. Van Lear and Watt (1993) suggested a theoretical prescription of understory burning in mature stands to enhance oak advance regeneration. Barnes and Van Lear (1998) tested this prescription and found that understory burning in mature stands did favor oak regeneration over competitors, but getting that regeneration to a competitive size would be a lengthy process and probably an unattractive option to most woodland owners.

In many parts of the eastern United States, dense shrub thickets of mountain laurel (*Kalmia latifolia*) and rhododendron (*Rhododendron* spp.) inhibit regeneration of oaks and other hardwood species (Moser et al. 1996, Baker and Van Lear 1998). Light understory burning in these situations has not proven effective in promoting oak regeneration. Moser et al. (1996) found, however, that intense fires that opened the overstory enhanced oak regeneration even where mountain laurel was a strong competitor. Results of this study suggest that a partial harvest of the overstory followed by prescribed burning may be beneficial to oak regeneration.

Brose and Van Lear (1998) and Brose et al. (1998) recently developed and tested a regeneration method that combines shelterwood harvesting and prescribed fire to favor oak regeneration in the Piedmont of Virginia. The prescription calls for an initial shelterwood cut in oak-dominated hardwood stands, followed in several years by a moderate- to high-intensity fire through the advance regeneration. This technique has successfully converted advance regeneration under mature mixed hardwood stands from yellow-poplar domination to predominately oak regeneration. In addition, the oak regeneration is of good form, competitively sized, and sufficiently free to grow so that it should be capable of forming a new oak-dominated stand when the overstory is removed (Brose et al. 1998).

This shelterwood-burn technique was tested on good-quality sites in the Piedmont of Virginia and may work well in other physiographic regions. If so, one of the most puzzling dilemmas in hardwood silviculture will be solved. A key ingredient of the prescription is achieving fires of sufficient intensity to significantly set back competing species. In this case, the silvicultural prescription simulates, to a degree, the combined events of overstory disturbance followed by fire, related events that have shaped the composition of oak ecosystems for millennia (Abrams 1992). Silviculturists still have much to learn from observing natural processes.

Stand-Replacement Fires to Restore Declining Appalachian Pine Ecosystems

Table Mountain pine and pitch pine have become rarer in the southern Appalachian Mountains during this century (Clinton et al. 1993, Turrill 1998). These species are thought to require intense crown fires for regeneration (Zobel 1969, Barden and Woods 1976, Groeschl et al. 1993). Decades of fire suppression efforts have prevented their regeneration and, as a result, pine stands have gradually succeeded to poor-quality oak-pine stands with a thick heath understory. Use of prescribed fire in the Appalachians has lagged behind that of other regions because of the perceived risk of controlling flames on steep slopes, erosion, and damage to hardwoods. Therefore, prescriptions for burning on these mountains are mostly experimental.

Groeschl et al. (1993) noted that a high-severity growing-season wildfire in Shenandoah National Park in Virginia promoted regeneration of Table Mountain pine. Results such as these account for the generally prevailing view that high-severity fires are necessary to regenerate this species. However, recent research indicates that spring prescribed fires of medium to high intensity, but of low severity, are sufficient to kill overstory trees, set back the dense understory of mountain laurel and rhododendron (*Rhododendron maximum*), and allow abundant Table Mountain pine regeneration in the mountains of Georgia (Waldrop and Brose 1998). Root systems of >80% of sampled seedlings were able to penetrate a duff layer of up to 7.6 centimeters thick, suggesting that exposure of mineral soil seedbeds was not a prerequisite for establishment of Table Mountain pine regeneration in this study.

Research by the Coweeta Hydrologic Laboratory of the U.S. Forest Service has demonstrated the importance and potential of high-intensity prescribed fires to restore pitch pine to mixed pine-hardwood ecosystems in the southern Appalachians (Elliott et al. 1999). As is the case with Table Mountain pine, natural succession replaces the pines with low-quality hardwood species in the absence of fire. Cyclic southern pine bark beetle (*Dendroctonus frontalis*) epidemics accelerate the rate of succession to hardwoods. Preliminary results of a high-intensity prescribed burn on the Nantahala National Forest in western North Carolina indicate that prescribed fire can increase pitch pine regeneration and restore vigor to this ecosystem.

Much has been learned in recent years about the ecosystem effects of these high-intensity burns from the multidisciplinary efforts of the Coweeta research team. Clinton et al. (1996) found that losses and recovery of carbon and nitrogen after high-intensity fires in the southern Appalachians are a function of fire severity. Nitrogen availability increased after burning, but no dissolved inorganic nitrogen moved off-site (Knoepp and Swank 1993). Damage to site productivity can be reduced if burning is conducted under conditions that minimize consumption of the forest floor. Swift et al. (1993) noted no increase in soil erosion from high-intensity, but low-severity, burns in the steep terrain of the southern Appalachians. Importantly, these studies demonstrate that high-intensity prescribed fires can be used to restore pitch and Table Mountain pines without adverse effects on-site and off-site in the southern Appalachians.

Prescribed Burning for Precommercial Thinnings

Natural stands of loblolly and other southern pines often regenerate so densely that growth, especially merchantable growth, is slowed dramatically. Overstocked stands have traditionally been precommercially thinned by machines, chemicals, or hand labor, if thinned at all. Because of the costs of these methods, many dense stands are not thinned, and growth stagnates before commercial thinning becomes an option. In theory, however, dense pine regeneration can be economically thinned using prescribed fire at a fraction of the cost of alternative methods (Wade 1993). It has long been recognized that fire naturally thins dense regeneration of ponderosa and longleaf pines, but silviculturists have shied away from using prescribed fire to accomplish this objective.

Wade (1993) used low-intensity backing fires to effectively thin dense, young loblolly pine stands with a sufficiently wide range in ground-line diameters to allow differential survival. Based on results of this study, a predictive model was developed that explained 92% of the variation in sapling mortality. Waldrop and Lloyd (1988) also successfully thinned a dense 4-year-old stand of loblolly pine using prescribed fire in the Coastal Plain of South Carolina. They indicated that prescribed burning can produce high economic returns. Use of prescribed fire to precommercially thin overcrowded stands requires considerable expertise and should not be attempted by inexperienced burners.

Prescribed Burning to Restore Ponderosa Pine Ecosystems

Ponderosa pine forests in the Southwest were maintained in open, parklike conditions prior to European settlement by frequent low-intensity fires and droughts, and perhaps by pest outbreaks (Cooper 1960, Covington and Moore 1994, Yazvenko and Rapport 1997). After Euro-American settlers migrated into the area, heavy grazing, fire suppression efforts, and climatic events favored establishment of dense thickets of ponderosa pine regeneration. The postsettlement forest began to show many signs of stress, including reduced primary production and tree growth (Oswald and Covington 1984), decreased rates of decomposition and nutrient cycling (Covington and Sackett 1984, Hart et al. 1992), reduced species richness (Uresk and Severson 1989), and increased severity of diseases (Yazvenko and Rapport 1997).

Covington et al. (1997) recognized the difficulty of restoring fire to ecosystems where fire has been suppressed for long periods of time. Decades of fire suppression had allowed the forest to develop a laddered structure that encouraged crown fires. Prescribed fire alone caused high mortality of presettlement trees. However, by reducing fuel loading with thinning and slash removal, subsequent prescribed fires more closely simulated historical surface fires. Early results of this combination of treatments increased soil moisture, mineralization and uptake of nitrogen, and photosynthetic efficiency of presettlement trees. Production of shrubs and herbaceous vegetation increased. This experimental approach has been implemented on an operational scale in an adaptive, ecosystem management approach to restore >1,200 hectares of ponderosa pine to presettlement conditions (Walters and Holling 1990).

Coniferous forests throughout the western United States are in a generally declining state of health (Weatherspoon and Skinner 1996). Exclusion of the low- to moderate-severity fires that once characterized much of the region is at least partially to blame for many of the current forest health problems. Restoration efforts, such as those of Covington et al. (1997), provide a model to achieve the proper balance between silvicultural cuttings, mechanical fuel treatments, and prescribed fire.

Possibilities for New Uses of Prescribed Fire

By the next time we meet in Edmonton, Alberta, there will be new advances in the silvicultural uses of fire to report. Work is already underway in using prescribed fire to restore mixed oak forests in Ohio (Sutherland 1998). Efforts to use fire to restore diversity and presettlement structure to the second-growth pine-dominated ecosystems of the Lake States are proceeding (Dickmann 1998). In old-growth forests in the interior West, prescribed fire and cable logging are being tested to determine whether reduced fuel loading and lower stand densities will produce a more sustainable old-growth forest structure (Fitzgerald 1998). Restoration of savannahs and prairies will be a priority in many areas of the United States.

Much remains to be learned about the effects of prescribed fire, or lack thereof, on wildlife. Brennan et al. (1999) state that many of the major wildlife management "problems" in the southern United States are the result of habitat loss because of fire suppression. Can a landscape dotted with pockets of public land where fire is likely to be frequently applied provide sufficient habitats to maintain declining species if burning is not also conducted frequently across the rest of the landscape? Researchers will seek the answers, but they may come too late for many species.

Fire suppression is, of course, an unnatural circumstance in fire-maintained ecosystems such as ponderosa and longleaf pine forests, where frequent surface fires were the historical norm. Less well recognized is the serious wildfire threat posed by the increasing accumulation and coalescing of flammable fuels in temperate and boreal forests, where the fire-return interval is longer. Zealous fire suppression can be considered a form of disturbance; it produces a state of disorder, which sets the stage for the undesirable effects of intense uncontrollable wildfires. Research is needed to determine how prescribed fire can best be integrated into land-management strategies that minimize risk of catastrophic wildfires, while still achieving other management objectives. A traditional use of prescribed fire—hazard reduction—needs to be revisited under the guise of ecosystem management, rather than stand protection.

Understanding Fire as an Ecological Process

Nearly all of the recent advances have resulted from a thorough recognition of the historical and ecological role of fire in forest ecosystems. The role of fire has been identified through the study of fire history. As Pyne et al. (1996) describe it, fire history begins with the geography and distribution of fires over time, unfolds with the evolution of fire regimes and how they affect the biota, and includes the ways that humans apply and withhold fire.

Fire histories are deciphered through various means, including interpretation of fire scars in the tree-ring record, the deposition of charcoal and pollen in lakes, and the use of old photographs. In addition, accounts of early explorers and settlers, while sometimes ambiguous, help us visualize the early forests and understand why Indians and early settlers frequently burned the woods. In some cases, we are fortunate to be able to use data from earlier research studies to document vegetative changes in the absence of fire. Changes in vegetative composition and structure from those early descriptions enable researchers to interpret effects of fire suppression.

The key to discovering new uses of prescribed burning is to understand the historical role of fire in the functioning of ecosystems. Ancient people thought the world was composed of 4 basic elements—earth, air, water, and fire. They understood the fundamental importance of fire. Perhaps modern people will one day recognize that importance.

Much remains to be learned about the potential uses of prescribed fire. Despite the acknowledged traditional uses of fire as a silvicultural tool, plus the recent advances mentioned here, the future of prescribed burning is still unclear. Smoke management remains one of the biggest obstacles to increased use of prescribed burning. As Achtemeier et al. (1999) point out, a collision is imminent between the air quality concerns (the Clean Air Act) and the increasing need for prescribed burning to maintain habitat (the Endangered Species Act).

Science will never be the sole criterion as to whether prescribed burning will be increased; social concerns and political pressures will be the overriding factors. Science can provide the public with information about the consequences of using or not using fire. The public must then weigh that information and make its wishes known through the political process. It is resource managers' responsibility to tell the public about the benefits of using prescribed fire because the detriments of wildfire are well reported in the media. Good news does not sell newspapers or get on television, but the public must understand the positive role that fire can play in restoring declining ecosystems, saving threatened and endangered species, enhancing natural beauty, benefiting wildlife habitat, and reducing risks of wildfire. Only if these benefits are well publicized will prescribed fire remain a significant ecological process in the landscape.

CONCLUSIONS

Although prescribed fire has been studied for more than 70 years, advances in its use are still being made. Advances are occurring because knowledge of ecosystems is increasing and we now more fully understand fire as an ecological process. The acceptance of ecosystem management, with its focus on the landscape, as a model for forest management is another important reason that the silvicultural use of prescribed fire is advancing. How can ecosystem management be implemented if we fail to incorporate one of the most important ecological processes—fire—into the plan?

Fire is critically important in shaping vegetative composition, structure, and function in many ecosystems. Because fire has been suppressed for most of this century, some of the most important recent advances in the silvicultural use of fire have been in restoring the character of fire-maintained ecosystems.

Recent advances in the use and potential uses of prescribed fire re-emphasize the importance of fire in many ecosystems. When fire is removed from fire-maintained or -dependent ecosystems, severe ecological consequences usually ensue. Overall ecosystem diversity declines, many native species become threatened or endangered, natural beauty suffers, and the general health of ecosystems is often degraded.

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