RESTORATION AND MANAGEMENT OF SHORTLEAF PINE IN PURE AND MIXED STANDS—SCIENCE, EMPIRICAL OBSERVATION, AND THE WISHFUL APPLICATION OF GENERALITIES

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ABSTRACT.—Shortleaf pine (*Pinus echinata* Mill.) is the only naturally-occurring pine distributed throughout the Ozark-Ouachita Highlands. Once dominant on south-facing and ridgetop stands and important in mixed stands, it is now restricted to south- and southwest-facing slopes in the Ouachita and southern Ozark Mountains, and to isolated pure and mixed stands in the northern Ozarks. Its position as a minority component in mixed stands has declined to the status of relict. Restoration and management of shortleaf pine fall into three categories—science, empirical observation, and wishful application of generalities. In science, knowledge exists about regenerating pure stands of shortleaf pine through plantation forestry or natural regeneration, about managing second-growth stands to restore pine-bluestem communities, and about applying growth and yield models for pure stands of the species. Empirically, evidence suggests that relying on advance growth rather than seedfall will better regenerate shortleaf pine naturally over time, in conjunction with prescribed burning. Generalities become more wishful when considering the use of herbicides to supplement fire, and when thinking about effective ways to underplant a minor and varying shortleaf pine component in hardwood stands so as to recover the dramatically depleted area of oak-pine woodlands—the omitted step in restoring this species fully in the Ozark-Ouachita Highlands.

INTRODUCTION

Shortleaf pine (*Pinus echinata* Mill.) is the most widely distributed and least well understood of the four major southern pines. 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, and is usually found in association 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, it is the only naturally-occurring pine. Here, shortleaf pine, pine-hardwood, and hardwood-pine stands once covered extensive areas.

Pine-dominated stands were and still are common in the Ouachitas. The folding and faulting of these heavily-eroded mountains date to late Paleozoic origin. The main axis of the Ouachitas runs east to west, which creates broad U-shaped valleys, long ridges, and hillside slopes dominated by northern and southern aspects. Site productivity is generally correlated with topographic position and colluvial pedogenesis, such that the ridgetops are the poorer sites and the lower slopes and valleys the better sites. The ridgetops and south-facing slopes in particular feature xeric conditions promoted by thin rocky soils and a high level of incident solar radiation, which favor microclimatic conditions under which the establishment and development of shortleaf pine is favored. Anthropogenic activity prior to European settlement kept fire on the landscape in a regular way. Periodic fire promoted shortleaf pine, perhaps at the expense of other pines, through shortleaf pine's adaptation of sprouting if the stem is killed or cut, a trait noted early on as an adaptation to surface fires (Mattoon 1915). Nowhere in the natural range of shortleaf pine does the species so dominate a landscape, and especially the stands on ridgetops and south-facing slopes within the landscape, as in the Ouachitas.

But shortleaf pine was also a dominant pine on the Ozark Plateau. Unlike the Ouachitas, the Ozarks are an uplifted calcareous plateau that has weathered over time into a landform that features benches underlain by resistant rocks at varying elevations. Due to vagaries of weathering and the distribution of underlying geology, slope aspect is distributed around all points of the compass. Site quality in the Ozarks is dependent on soil depth, which can vary considerably by slope position, depending on the presence or absence of these benches at differing elevations. As a result, site conditions are far more heterogeneous in the Ozarks than the Ouachitas. The Ozarks have many varied aspects rather than a few. Uniform site conditions are

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featured in a much smaller area, and where the best sites on a hillside might be on a bench toward the upper end of the slope. These conditions are suited to a pine that is very much a generalist, which is more the typical pattern of shortleaf pine throughout its natural range. Again, under the actions of drought and fire, shortleaf pine undoubtedly was and is found in pure stands in the Ozarks, but these stands are less contiguous than in the Ouachitas. Moreover, shortleaf probably existed as a varying majority or minority component in mixture with hardwoods across the Ozarks, depending on site conditions and disturbance history.

For those interested in the ecological restoration of shortleaf pine, a key question concerns restoring the mixed pine-hardwood and especially the hardwood-pine stands where shortleaf was found. The heyday of lumbering in the Interior Highlands was highlighted by high-grading shortleaf pine. The Missouri Mining and Lumber Company operated shortleaf pine mills at Grandin, MO, from 1888 to 1909 and cut about 75 million board feet (bf) annually (Flader 2004). Roughly speaking, that mill alone cut from 1.2 to1.5 billion bf from southern Missouri—a volume exceeding one-third of the standing sawlog volume in the shortleaf-loblolly pine species group in the Missouri Ozarks today (Miles 2006). That quantity speaks to a ruthless high-grading of shortleaf pine throughout the southern part of Missouri. Operationally speaking, this pine harvest could not have been taken simply from pure stands. Logging crews for the Grandin mill and others must have cut shortleaf pine trees wherever they were found, whether in pure stands on southerly aspects or even just a few trees in an oak-dominated stand.

If a stand was dominated by shortleaf pine before being high-graded, it had at least a chance of returning to shortleaf. Pines smaller than the accepted merchantable size would not have been cut; those small trees were probably mature, and would have dispersed seed on a recently harvested site that had sufficient exposure from logging and skidding so as to present a relatively favorable seedbed for shortleaf regeneration, especially if surface fires contributed to site preparation and competition control. Similar natural dynamics undoubtedly followed harvest of pure stands of shortleaf throughout the Interior Highlands, and must have been effective judging by the extent of second-growth shortleaf pine stands throughout the region.

But a different dynamic arguably ensued in hardwood-dominated stands. There, loggers looking for pines would not have cut the hardwoods, they would have cut only the few pines sought by their mill. A high-grading that took five or ten shortleaf pines per acre and left all the hardwoods would not have caused a sufficiently intensive disturbance to result in a new age cohort of shortleaf pine. These stands probably responded to pine logging as essentially a crown thinning, resulting in more growing space for the overstory hardwoods. Far fewer shortleaf pines were probably left as a seed source, and overstory hardwood shade would likely inhibit development of any shortleaf that persisted or were newly established in the understory. These speculations lead us to suspect that local extirpation of shortleaf pine was more likely in mixed stands than in pure stands, and especially in the oak-pine stands where pine was a minor component initially. Evidence of that extirpation exists today in stands that contain no shortleaf pine, but in which we can still find scattered shortleaf pine stumps. Such stands are not uncommon in the Missouri and Arkansas Ozarks.

The implications of this are interesting in light of the fact that restoration of shortleaf pine is moving forward. The silvicultural basis of ecological restoration includes re-initiation of suppressed ecological processes (e.g., fires), removal of encroaching native and exotic species, and the establishment of the native species that once dominated the landscape. This prescription is fairly straightforward when the native species is in relatively pure stands, as seen in the pine-bluestem restoration projects being undertaken by each of the three national forests in the Interior Highlands, and by the oak woodland restoration projects under way on the two national forests in the Ozarks. There are also opportunities in the restoration of mixed pine-oak and oak-pine stands in the region.

However, the research to support restoration of shortleaf pine is incomplete. Some elements are firmly established in the scientific literature and in practice, but other elements are based on empirical silvicultural tactics that we think we know but that are not yet firmly established in the literature. And some elements are unusually speculative, based on what could be considered the wishful application of generalities (WAGs) that can be derived from the silvics and silviculture of shortleaf pine. In this paper, elements important to consider in application of silvicultural concepts to shortleaf pine will be reviewed for each of these three elements—science, empiricism, and WAGs.

SCIENCE UNDERLYING SHORTLEAF PINE SILVICULTURE

A number of elements of shortleaf pine silviculture that can be applied in restoration prescriptions are drawn from good scientific findings firmly accepted in the literature. One set of findings can be taken from existing science that was originally intended to support productive management of shortleaf pine for timber products. The other set has been developed largely in direct support of pine-grassland habitat restoration, of direct benefit to the endangered red-cockaded woodpecker but also of great value in bringing back a suite of associated species originally found in pine-bluestem woodlands.

Planting Shortleaf Pine for Restoration

If a restoration decision is made to reforest or afforest a site with shortleaf pine where no natural seed source is available, the most direct approach is to use artificial regeneration. The science that supports artificial shortleaf pine regeneration is well established, largely through the actions of the shortleaf pine artificial regeneration task force of the late 1980s and reviewed elsewhere in these proceedings (Barnett and Brissette, this volume). In a nutshell, planting works well with shortleaf pine, especially when incorporating advances in seed and seedling quality (Barnett 1992). Among the important considerations for success was development of target seedlings in the nursery that were larger than had been produced previously (Brissette and Carlson 1992), which is consistent with commonly-accepted general trends that point to greater success with larger planting stock for any number of pine and hardwood species in the South over the past decade.

A second key factor in successful plantation establishment on the Ouachita NF was the site preparation treatment of ripping or subsoiling, in which a vertical steel bar is used to essentially plow a furrow from 12 to 18 inches deep in the rocky hillside soil during the late summer of the year prior to planting. Data suggest that ripping alone increased seedling survival by 10 to 30 percent (Walker 1992), from roughly 50 percent to 80 percent. Ripping is typically used to ameliorate planting conditions in soils with a prominent fragipan, but Ouachita soils do not have fragipans. Inspection of the rips suggests why they might be effective. During the 6 months between ripping and planting, rainfall dislodges soil particles l from the sides of the furrow toward the bottom, a microcolluvial effect that fills the cracks and fissures in the base of the furrow with several inches of soil fines (Fig. 1a). The seedlings are then planted in that thin layer of soil. Subsequently, when temperature and drought stresses reach their maximum late in the summer during the first growing season, that small amount of soil in the furrow provides a rooting medium for the seedling that moderates extremes of temperature and soil moisture deficit compared with a seedling planted directly in these rocky soils (Fig. 1b). These conditions contribute greatly to reduced seedling mortality.

Figure 1a.—Ripping promotes first-year survival of planted seedlings through microcolluvial deposition within the rip. Ripped furrow shortly after being created in the summer prior to planting (photo by James M. Guldin).

Figure 1b.—Shortleaf pine seedling planted in the ripped furrow, in August of its first growing season (photo by James M. Guldin).

Restoration Prescriptions

The prescription applied to immature and mature shortleaf pine stands for restoration or recovery of shortleaf pine woodlands is essentially a series of intermediate treatments (sensu Smith and others 1997). Those treatments are intended to promote habitat favorable to the endangered red-cockaded woodpecker, with attendant benefits to a number of associated woodland flora and fauna (Fig. 2). Hedrick and others (this volume) summarize that work with a synthesis of empirical treatments needed to execute the prescription, and a summary of numerous studies that have quantified fire occurrence and treatment effects on flora and fauna (Masters and others 1995, 1996, 1998; Sparks and others 1998, Wilson and others 1995, Cram and others 2002) and related ecological, economic, and silvicultural effects (Huebschmann 2003, Thill and others 2004, Guldin and others 2005, Liechty and others 2005).

Figure 2.—Restored stand in the pine-bluestem restoration area on the Ouachita NF, Scott County, Arkansas (photo by James M. Guldin).

The key elements in this prescription, in order of implementation, are using tree cutting to simulate natural disturbance patterns, removing the midstory hardwoods that have encroached upon the stand in the absence of fire for the past seven decades, and increasing the use of prescribed fire (Bukenhofer and Hedrick 1997, Guldin and others 2005). The studies cited have all explored the separate or combined effects of the thinning, midstory reduction, and burning, and it appears that in practice all three treatments are required to consistently give best results.

Restoration Applications of Growth and Yield Models

Finally, there are opportunities in restoration prescriptions to apply existing growth and yield models, especially individual-tree models that generate stand tables by diameter class. This is not the first time that timber-based models of stocking and growth have been of use to ecologists, because they can be used to quantify biomass, snags, woody debris, and other tree-based attributes that can be efficiently modeled with an understanding of tree size. In the Ouachitas and southern Ozarks, the Shortleaf Pine Stand Simulator model (Huebschmann and others 1987) provides a first-rate tool to model the development of naturally regenerated shortleaf pine stands, whether even-aged (Lynch and others 1999) or uneven-aged (Huebschmann and others 2000). The model requires input of stem density by diameter class and gives users a tool to predict growth over different time horizons of different intensities of treatment.

While growth and yield models have traditionally been interpreted from a timber-based perspective, it is equally appropriate to use a model such as this to evaluate stand development alternatives under different levels of commercial thinning in a restoration prescription. Individual tree models generate stand and stock tables that contain data on diameter distributions in terms of stem density by size class. To apply growth and yield models in the context of restoration, foresters should quantify desired future conditions using stem density by diameter class, and then apply the growth and yield models to analyze the degree to which different treatments might develop the target diameter distribution. These models might be especially meaningful in prescriptions that seek to accelerate mean stand diameter growth past a minimum threshold in a managed old growth context, to calculate changes in volume over time if leaving living relicts or snags of a given size and density, and so on.

EMPIRICAL EVIDENCE SUPPORTING SHORTLEAF PINE SILVICULTURE

The creative application or extension of known silvicultural practices and refinement of new practices for restoration of shortleaf pine fall less into the realm of known science and more into the realm of well-founded empirical experience. Some of these empirical advances relate to using old authorities in new ways and under new interpretations. Others relate to no less than the practical development of new techniques by personnel in the field rather than by scientists in a lab or academic setting.

Reinvestment of Harvest Proceeds in Restoration Treatments

The example of old authorities being interpreted and applied in new ways to new situations is nowhere more apparent than on National Forest System lands. Here, the old authority was the Knutsen-Vandenberg (KV) Act of 1933, which allowed Forest Service land managers to reinvest a portion of the harvest proceeds in reforestation of harvested areas. The reinterpretation of the authorities under the KV Act to allow for not only reforestation but also for general improvement of forest stand conditions within the sale area has opened the door for KV funds to be spent on reforestation not only by artificial regeneration, but also by natural regeneration. In addition, activities undertaken to improve forest conditions such as treatments to promote specific habitat conditions have also come to be interpreted as within the scope of the KV Act.

This is important because the KV Act provides funds beyond those appropriated funds authorized for annual agency activities. Because of competing agency priorities for increasingly limited appropriated funds on an annual basis, it is difficult to achieve restoration goals over ecologically significant areas through reliance on appropriated funds alone. The concept of the KV Act is also meaningful to private landowners, whose sole source of funding for treatments they choose is frequently a reinvestment of harvest proceeds.

Nowhere has a more creative blending of these authorities been practiced than in the shortleaf pine-bluestem restoration prescription in the National Forests of the Interior Highlands, especially the activities under

Management Area 22 on the Ouachita NF (Bukenhofer and Hedrick 1997, Guldin and others 2005, Hedrick and others, this volume). The commercial thinning of shortleaf pine in the restoration prescription provides appropriations-strapped National Forests with KV-based funds to support follow-up midstory and burning treatments. Those treatments can then occur for a longer time (as much as 10 years for follow-up prescribed burning) and over a much wider geographic area than could be afforded using appropriated dollars alone. In essence, part of the value of the standing volume of shortleaf pine sawlogs in excess of that needed for restoration is used to fund the restoration prescription.

This management tactic works as well as it does in western Arkansas because of the continued presence of a strong and viable local lumber manufacturing industry in the region. A model of timber sales for the region shows that bids are correlated to both the volume of pine sawtimber offered in the sale and to the ratio of the prevailing dimension lumber price index to the sawlog price index, a factor affecting mill conversion opportunities in a given market (Huebschmann and others 2000). The existence and proximity of lumber mills that manufacture pine dimension lumber from pine sawlogs are a key elements to the success of this tactic.

Use of Prescribed Burning

Prescribed burning has increased dramatically on National Forest lands in the region, but few others on forest industry or private lands apply the technique. A wider use of prescribed burning on other land ownerships in the region is not likely to occur because of legal issues that surround liability for prescribed fire, the perception that burning results in some minor growth loss, concerns about smoke management, and a still-strong attitude within the professional community that fires should be controlled rather than set. Even within Federal ownership, burning can vary by district because of differences in planning, application, and commitment of district personnel to the effort.

Prescribed burning requires considerable expertise to employ effectively. Probably no element of silvicultural practice is more difficult to translate from the classroom to the woods. Much of the education obtained when using prescribed fire occurs when things do not go quite as planned. The accumulated wisdom of the professional and technical personnel who conduct this burning program is an invaluable asset for meeting the commitments required for effectively using this tool on a landscape scale.

As with many agencies, however, U.S. Forest Service personnel represent a graying workforce and the districts that employ them are increasingly on limited budgets. District professionals also have responsibility for larger areas than a decade ago because of the prevailing trend for consolidation of ranger districts over that period of time. Ideally, the tenure of the old, outgoing professional would overlap with that of the young, incoming professional, to allow for translation of some of the experience-based knowledge from predecessor to new employee. But that situation is nearly impossible to achieve under the budgets with which the agency is working. Consequently, retirements and changes of duty station often diminish the district's capability to maintain a prescribed burning program. The technicians often become the bridge, and they are graying also.

Reproduction Cutting Methods other than Clearcutting

The use of reproduction cutting methods other than clearcutting is on the rise on National Forest land in the Interior Highlands, a trend mirrored by the use of natural regeneration rather than planting for reforestation after reproduction cutting (Guldin and Loewenstein 1999). The shift away from clearcutting and toward methods of cutting that rely on natural regeneration was triggered by the Walk in the Woods on the Ouachita NF (Robertson 1999). Recent forest planning activities on the Ouachita NF, Ozark-St.Francis NF, and Mark Twain NF suggest that this trend will continue.

Research on reproduction cutting methods that rely on natural regeneration has not kept pace with the application of the practice. Interim results 5 years after reproduction cutting in the Ouachita Mountains Ecosystem Management Research Project (EMRP) suggest that all reproduction cutting methods can be made to work, but that some work better than others (Guldin and others 2004a, 2004b). Regeneration in the shelterwood stands has not yet been subject to damage commonly associated with the partial removal cut of residual overstory trees, nor has the regeneration in the uneven-aged stands experienced the subsequent cutting cycle harvest; both of these activities are known to cause mortality that in the long term might affect sapling survival. Moreover, this study was installed without the use of prescribed fire as part of the site preparation, and different results are expected in the presence or absence of prescribed fire when conducting reproduction cutting. To be useful on both public and private forest lands in the region, robust silvicultural tactics associated with reproduction cutting must be developed in situations where fire can be used, and also where it cannot be used.

The lag between research and practice is evident in the preference of practicing silviculturists to employ the seed-tree and group selection methods, which interim research results suggest might be less effective than the shelterwood and single-tree selection methods (Guldin and others 2004a, 2004b). Practicing silviculturists point to the advantage of using prescribed fire as a site preparation tool in seed-tree stands to prepare a seedbed for pine seedfall. They also suggest that administrative advantages of group selection relative to single tree selection include greater efficiency in (1) contracting site preparation and release treatments; (2) logging (groups serve as logging decks); and (3) retention of hardwoods for wildlife and aesthetic reasons in the matrix between the group openings. These elements suggest that research scientists have more work to do to better quantify regeneration dynamics and development under these popular methods for application, especially if there are some yet-to-be-answered questions about stocking and distribution of regeneration resulting from their application.

Shortleaf Pine Seedfall

An understanding of seed production in natural stands of shortleaf pine is important in managing for natural regeneration of the species, and recent work had added to our understanding of this. Shelton and Wittwer (1995) analyzed 9 years of shortleaf pine seedfall data collected in the 1960s to 1970s. The study suggested that three to five adequate or better seed crops per decade, with an average of 100,000 seed annually. There was considerable geographic variation in seedfall, with higher amounts in the eastern Ouachitas and lower amounts in the western Ouachitas. Seedfall was also positively related to stand age and negatively related to pine and hardwood basal area, suggesting that overstocking and competition inhibit crown expansion and cone production in the pine component. Wittwer and others (2003) reported on a more recent seedfall study within the Ouachita EMRP; over a four-year period, seed crops were good, poor, poor, and bumper, with differences by reproduction cutting method in the first good crop but not the last. Their results suggest a crown response in shortleaf pine to cutting methods that reduce canopy competition, which was also noted by Wittwer and others (1997) when comparing seed tree versus single-tree selection stands. In summary, these studies suggest that in shortleaf pine stands, especially those that have been thinned prior to harvest (but not late in the rotation), adequate or better seed crops sufficient to regenerate shortleaf pine can probably be expected in two of three chances when using the seed-tree method (Shelton and Wittwer 1995). The odds are longer farther to the west of the Interior Highlands.

The commonly used subjective empirical tools for seed prediction—such as cone counts with binoculars, or inspection of the crowns of pines harvested in logging jobs, during the summer before seedfall—do not allow foresters to predict an average or better seed crop in a given season more than a few months in advance, or to make plans to take advantage of a forecast for a good seed crop. For example, logging activity is known to scarify the forest floor, and the exposed bare mineral soil that results is an excellent seedbed for natural seedfall of southern pines (Baker and others 1996). But a forester will have only a few months between prediction of a bumper seed crop and the seedfall itself. On private lands with limited acreage, landowners or the foresters who advise them can often arrange a small timber sale on short notice in a stand where reproduction cutting is desired, so as to catch a predicted seed crop on the freshly exposed soil of the forest floor.

But silvicultural operations take place more or less continually on larger holdings such as national forest lands or forest industry lands, and there is less opportunity to tailor a silvicultural treatment to take advantage of an ephemeral window for seedfall. Provisions in timber sale contracts on national forests often allow a multi-year window (3 years is typical in the South) for completion of the harvesting; loggers are free to operate at any time within that window provided that conditions are appropriate for forest operations. Timber sale contracts can and often do specify the months during which operations can and cannot occur, so as to avoid detrimental impacts of harvesting at specific times of the year (such as during the breeding season for wild turkey). But those contracts cannot specify the exact year within the multi-year window of the contract that harvesting is to occur, and this inability makes it risky for a forester to rely on the silvicultural tactic of having natural seedfall occur immediately after a logging operation. The remedy is to plan for supplemental site preparation independent of the logging job, where we can better control the timing of the operations through contracts for specific treatments within a given year.

WAGS ABOUT SHORTLEAF PINE SILVICULTURE

There is no shortage of topics for advances to be made by silviculturists either in research or active management positions. Some of these opportunities for advancement transcend the Interior Highlands—such as managing mixed stands, especially those having a minor and varying pine component. Others are unique to shortleaf pine, including answers to basic questions about the biology and silvics of this species. The topics that are proposed are interesting in that if shown to be true, they might find wide application in developing and using silvicultural practices in shortleaf pine management and restoration.

The Natural Range of Loblolly Pine

There are curious elements about the natural range of loblolly and shortleaf pine that suggest ecologists and silviculturists have incompletely understood these species and the ecological circumstances and adaptations that govern their distribution. The northwesterly limit of the natural range of loblolly pine in the region coincides with the limit of the upper West Gulf Coastal Plain and the Athens Piedmont Plateau, where it is found as a dominant pine in stands having a minor and varying shortleaf pine component. There is some evidence to suggest that perhaps this mixture was dominated by shortleaf pine 70 years ago, mostly evident through the persistence of early forest scientists in the region referring to those Coastal Plain stands as "shortleaf-loblolly pine" stands (Reynolds and others 1944, Reynolds 1947).

Interestingly, the transition from mixed pine stands to pure shortleaf pine stands occurs within a range of about 20 miles, with a few scattered loblolly pine-dominated stands in transition. This is an unusually rapid ecological transition, which, while certainly influenced by the rise of the southern part of the Ouachita Mountains in that area, cannot be solely explained by the obvious actions of climate, weather, geology, flora, fauna, or humans. We might speculate that fire played a role, or ice storms, or anthropogenic burning prior to European colonization. While these factors might explain a gradual change across the Ouachitas generally, they do not explain the sharp transition that actually exists. If a causal ecological agent for this disappearance of loblolly from mixed pine stands could be elucidated and quantified, it might be of considerable ecological interest in the context of shortleaf pine restoration. It might also be possible to use that knowledge to develop silvicultural restoration tactics that favor shortleaf pine in stands that had been converted to loblolly pine by forest industry landowners, especially on that portion of the industry land base that has been reacquired by Federal land managers through purchase or exchange.

Advantages of the Sprouting Habit of Shortleaf Pine

The sprouting habit of shortleaf pine (Fig. 3) might be useful in silvicultural applications for natural regeneration in pure and mixed stands beyond that for which it is being used today. In an environment that features frequent surface fires, logic suggests that any given fire will result in topkilled seedlings that subsequently resprout, and might also create seedbed conditions favorable to germination of new seedlings. The sprouts and seedlings combine to create a new cohort that persists in the understory until a subsequent surface fire, which again promotes resprouts of the previous cohort as well as new germinants in the burned seedbed. Over time, this process of seedling establishment and resprouting after a series of fires should result in a bioaccumulation of pine seedlings and sprouts, constituting a stored seedling bank awaiting overstory disturbance to develop into the pine component of a new stand.

If properly applied, this stored seedling bank could make natural regeneration of shortleaf pine in managed pine stands more certain in any given year, even those in which an adequate or better seed crop is not expected. Applying late-rotation prescribed fire would be instrumental in development of the seedling bank. This prescription would be useful to circumvent the problems in seedfall timing promoted by the multi-year logging windows of modern timber sale contracts. It would be especially useful in the seed-tree method to circumvent problems of understocking due to limited seedfall.

In principle, this tactic might be applied to any of the even-aged or uneven-aged reproduction cutting methods used for natural regeneration. Several cycles of prescribed burning in properly-thinned stands prior to reproduction cutting would initiate the process. Executing the reproduction cutting would require suspension of the burning program for a cycle or two, so that the saplings could grow sufficiently so as not to be topkilled when prescribed fire is returned to the stand. This approach is being studied in the pine-bluestem management area on the Ouachita National Forest, and in a study of prescribed fire in seedling stands on the Ozark-St.Francis National Forest, as first steps in quantifying whether this bioaccumulation is silviculturally feasible.

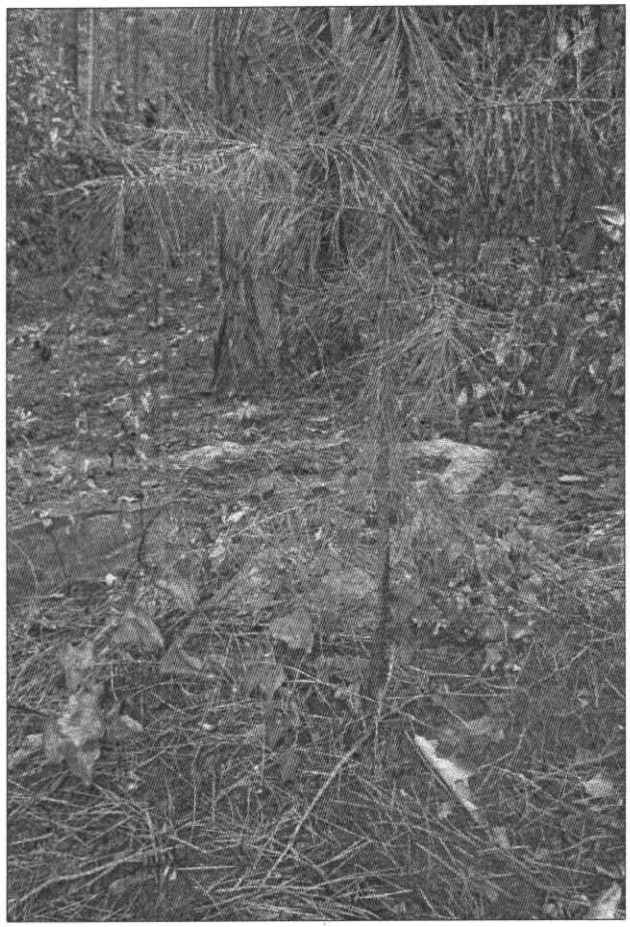

Figure 3.—Shortleaf pine seedling sprouts emerging several weeks after the shoot was topkilled by a growing season prescribed fire, Ouachita NF, Scott County, Arkansas (photo by Richard Straight).

Mixed Pine-Oak and Oak-Pine Stands

Very little is known about the silvicultural practices needed to manage mixed stands of shortleaf pine and hardwoods in the region (Fig. 4). The fundamental premise in managing mixed stands is to use silvicultural practices that can be successfully applied for each of the species in the mixture, and to avoid those practices that discriminate against the species sought in mixture. Conceptually, the simplest approach to regenerating a mixed stand is to successfully

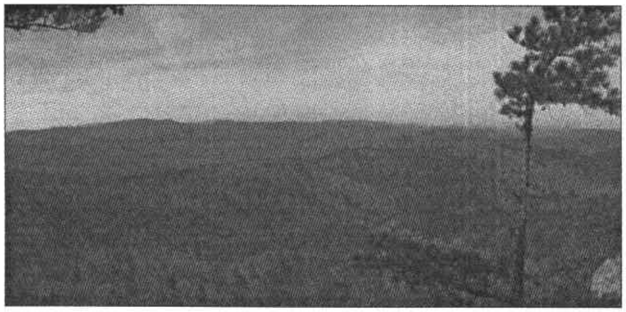

Figure 4.—A westerly view in the eastern Ouachita Mountains, Saline County, AR. The view illustrates the dominance of pines on south-facing slopes and the dominance of hardwoods on north-facing slopes in these east-west oriented ridges (photo by Rudy Thornton).

regenerate each of the species that are sought, and then to use individual-stem release treatments to adjust the proportions of species in the mixture to some desirable standard. This approach has been used in empirical practice on national forest lands, especially in pine-oak stands where pines are either planted or obtained through natural regeneration and where oaks are brought in through stump sprouts or advance-growth seedling sprouts.

Management of mixed oak-pine stands is more difficult because it is inherently difficult to regenerate just a few pines in a cohort dominated by oaks and other hardwoods. A stand being regenerated to hardwoods in the region is not likely to have a nearby pine seed source, either because pines may not be adapted to that particular site or because the pines that were adapted to that site may have been removed decades ago through partial cuttings. Nor has it been a traditional practice to plant just a few dozen pines per acre in a stand being regenerated to hardwoods. And even if a small number of pines were established naturally or by planting following a reproduction cut, they would be at a competitive disadvantage relative to sprout-origin hardwoods because sprouts grow more rapidly than seedlings.

If we accept the premise that mixed oak-pine stands were once common in the region and are no longer, and that efforts should be made to restore them, the silvicultural tactics for restoration of a minor pine component in an oak-hickory stand become of more than academic interest. To do so, we should separate establishment of pine seedlings and their development. Establishment will probably require direct silvicultural intervention, and development dictates using an advance growth strategy to promote the pines as well as the oaks.

To get pines established, we would rely on happenstance establishment of pine seedlings and on artificial regeneration. We might start by promoting the survival and growth of any pine seedlings or saplings that might exist in the stand understory. We would also plan to retain any existing natural seed sources in or adjacent to stands being regenerated in case seedlings appear through rare long-distance dispersal processes such as wind dissemination of seed over extraordinary distances, or through animal activity. And, we would probably work to successfully plant or underplant a few pines prior to or during harvest. But recommendations have yet to be established about planting density, pattern, or spacing. There might be some wisdom inherent in clustered planting of pines in a small multi-stem cohort such that pines in the center of the cohort would be subject only to intraspecific competition rather than the interspecific competition of hardwoods.

Further development of the mixed-species regeneration cohort through the sapling stage, especially in oak-pine mixtures, will certainly require individual-stem release treatment to obtain the desired proportion of oaks and pines in the mixed stand. Since we know so little about regenerating only a few pines in an oak-pine stand, we could always fall back on the most traditional silvicultural tactic based on practices intended to achieve pine dominance. Arguably, the most certain way of regenerating a small pine component in oak-pine stands is to aggressively work to establish a much larger number of pines than desired, and then aggressively kill most of them during a cleaning or release treatment. Admittedly, this is the costliest and least clever way to achieve this silvicultural objective, but it might serve as an interim measure until a better understanding of the natural oak-pine regeneration dynamic is obtained, which can then be emulated silviculturally.

The sprouting ability of shortleaf pine offers extraordinary potential along these lines also. This habit has much in common with the advance growth dynamic of oaks, and could possibly be developed as a legitimate pine-hardwood—or, more importantly, a hardwood-pine—regeneration prescription. The silviculture of oak requires planning for regeneration on the order of two decades in advance of harvest, with late-rotation thinning doubling as preparatory cutting and midstory removal of competing hardwoods required to promote advance regeneration of oaks (Johnson and others 2002, Loftis 1990). Adding prescribed burning to this prescription might be useful in promoting oak advance growth through topkilling and resprouting of seedling sprouts of oak. If a shortleaf pine seed source is available, some pines might be recruited and promoted in the mixed-species advance growth cohort. If no pines are present, and silviculturists seek a pine component in such a stand, they might be planted in conjunction with the prescribed fire program (such as immediately following or in the dormant season following a given fire, depending on when the burn is conducted) at whatever density the silviculturist seeks.

When this mixed-species regeneration cohort is ultimately released for recruitment into the overstory, the pines should respond much as do the hardwoods—which would give the pines a stronger competitive position with respect to the hardwoods than new seedlings would have, because they would have larger root systems built during their time as advance growth. Fine-tuning the mixture would also then be possible during precommercial release treatments 5 to 10 years after the initial overstory recruitment treatment (Fig. 5). Considerable research would be needed to precisely quantify the number, density, and timing of advance planting of shortleaf pine to attain given levels of shortleaf pine in mixture with hardwoods a decade or two after being released, especially for the oak-pine management objective. But using fire to deliberately trigger the topkill and resprouting would be consistent with the natural ecological dynamic for both pines and oaks, which seems not unlike the prevailing ecological influence in these forests in presettlement conditions.

Finally, there may be potential in retaining part of the pine overstory for an extended period of time. The straight-line and tornadic windstorms that periodically disturb pine stands in the Ouachitas occasionally leave a minor and varying overstory pine component on the site after the disturbance. Those escapees from the disturbance may have an important role in subsequent seeding of pines, and development of a mixed pine-hardwood regeneration component, over time. We might speculate that this new cohort might tend more to the pine component if fire had recently occurred in the understory prior to the wind event, to the hardwood component if fire had not recently preceded the windstorm, or again to the pine component if fire followed soon after the windstorm. The balance between use of fire to promote a mixed pine-hardwood regeneration cohort and the retention of pines and hardwoods as an older age cohort will be of interest to foresters in the 21st century, but much work remains to be done to better quantify these ideas.

CONCLUSION

Planting shortleaf pine will be required to restore the species on sites where it currently is not, such as abandoned agricultural or cutover land in the Interior Highlands. Ripping has been shown to be essential to improve survival of planted shortleaf pine. But the site-wide disturbance of the soil associated with ripping may be inconsistent with other restoration objectives, such as minimal disruption of the forest floor. Site preparation techniques must be developed that have the advantages of ripping for seedling survival but not the adverse effects on the forest floor throughout the stand. It seems that a localized soil disturbance of 3 feet or less in size might achieve the same advantages as ripping in microcolluvial soil deposition, and might better emulate a common natural soil disturbance event in nature—the uprooted root ball of a windthrown tree. Proper development of this site preparation treatment would also offer potential for localized collection of water, which might be useful for local populations of herpetofauna as well.

Figure 5.—A precommercially-thinned regeneration cohort beneath a shortleaf pine shelterwood in Scott County, Arkansas. The deliberate objective was to release both pines and oaks to promote a mixed pine-hardwood regeneration cohort (photo by Richard Straight).

The treatments associated with the shortleaf pine-bluestem restoration prescription to convert immature and mature second-growth shortleaf pine stands to pine-bluestem woodlands have to date relied upon the use of cutting and burning to remove the midstory hardwoods that built up in the stand through the period of fire exclusion over the past seven or so decades. But chainsaw felling and restoration of cyclic prescribed fires have not been sufficient to remove the rootstocks of those midstory hardwoods, and sprout clumps associated with those rootstocks persist in restored stands though multiple prescribed fires (Fig. 6). A more complete removal of these stems might be possible using herbicides

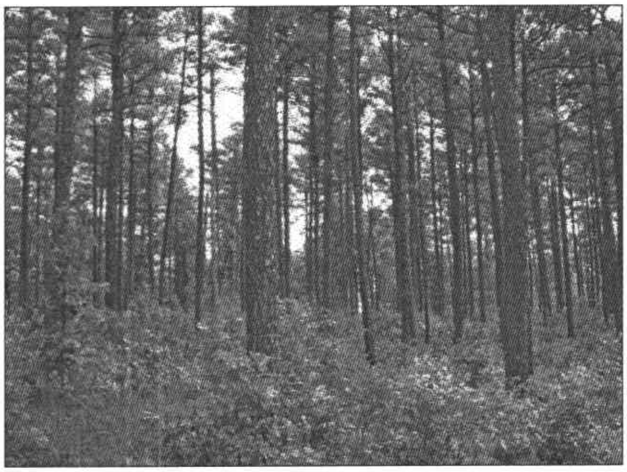

Figure 6.—A stand that meets the goals of pine-bluestem restoration in the western Ouachita Mountains growing seasons after prescribed burning, Scott County, Arkansas; hardwood resprouting is prominent (photo by Richard Straight).

that target mortality of the entire plant, not just the above-ground part. Herbicide use admittedly is unpopular on Federal ownerships, but there might be a place for limited stem-specific applications such as when the initial midstory removal treatment is implemented. More information is needed as to different qualities of understory condition in the presence or absence of these resprouting rootstocks to make better decisions about whether to remove them with unpopular herbicide prescriptions. That information could be especially useful in extending the restoration to private lands, where a carefully timed herbicide application might be less constrained than on public forest land.

Successful restoration over a broad area requires a thriving local timber industry. No doubt some might feel this is oxymoronic, but strong mill capacity and a regional market for pine sawtimber create opportunities for national forest land managers to provide commercial timber for sale; they can then use some of the profits from those sales to restore larger areas of a landscape than would be possible without those markets. Interestingly, many of these mills also purchase sawtimber from adjacent forest industry lands, which can in part provide alternative sources of supply for those mills when sales on national forest land become limiting. Thus, an intermingled ownership that allows local sawmills to buy timber from private lands when national forest timber sales are periodically limited may also be a positive element that promotes large-scale habitat restoration on the federal land base in the region.

Silviculture has been defined as both an art and a science, and there is probably no element of the body of silviculture more characteristic of the art than the application of prescribed burning as an intermediate treatment and in reproduction cutting. Efforts should be developed, perhaps through cooperation with state forestry or heritage agencies and conservation organizations, to develop regional prescribed fire training academies in the Forest Service that would provide some of the practical experience that seems to be more critical in application of burning than any other silvicultural practice. The staff of the academy could in part be composed of recent retirees from these agencies experienced in the use of the tool, and rehired to work in the incident command structure for wildfires and disaster response.

The broad set of reproduction cutting methods imposed in the Ouachita Mountains EMRP was constrained by their size and breadth of scope. The influence of prescribed fire on pine seedling recruitment and on the balance of regeneration through sprouting and new seedlings must be understood. Research should concentrate on the full spectrum of mixed-species stand dynamics as well, with efforts to quantify the effect of supplemental pine planting in advance of harvest under a burning program for goals of restoring both pine-hardwood and hardwood-pine stands on appropriate sites. An advance-growth seedling bank approach to shortleaf pine silviculture offers tremendous opportunity for silvicultural application in pure and mixed stands, and provides tactical advantages in simplifying regeneration establishment and development under the uncertainty of shortleaf pine seed crops and the timing of harvesting operations.

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