Proceedings of the 2007 National Silviculture Workshop

Restoring Old-Growth Southern Pine Ecosystems: Strategic Lessons From Long-Term Silvicultural Research

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ABSTRACT

The successful restoration of old-growth-like loblolly (***Pinus taeda***) and shortleaf (***Pinus echinata***) pine-dominated forests requires the integration of ecological information with long-term silvicultural research from places such as the Crossett Experimental Forest (CEF). Conventional management practices such as timber harvesting or competition control have supplied us with the tools for restoration efforts. For example, the CEF's Good and Poor Farm Forestry Forties have been under uneven-aged silvicultural prescriptions for 70 years. Monitoring these demonstration areas has provided insights on pine regeneration, structural and compositional stability, endangered species management, and sustainability capable of guiding prescriptions for old-growth-like pine forests. Other studies on the CEF's Reynolds Research Natural Area have provided lessons on the long-term impacts of fire suppression, woody debris and duff accumulation, hardwood competition, and pine regeneration failures. This experience leads us to believe the productivity and resilience of these forests can be adapted to create functionally sustainable old-growth-like stands by integrating silviculture and restoration.

Keywords: coarse woody debris, Crossett Experimental Forest, loblolly pine, red-cockaded woodpeckers, shortleaf pine, Upper West Gulf Coastal Plain.

This paper was published in: Deal, R.L., tech. ed. 2008. Integrated restoration of forested ecosystems to achieve multiresource benefits: proceedings of the 2007 national silviculture workshop. Gen. Tech. Rep. PNW-GTR-733. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 306 p.

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Figure 1—Examples (a) of the presettlement pine forests that once dominated the Upper West Gulf Coastal Plain of southern Arkansas and (b) of the cutover landscapes found by the early 20th Century.

Figure 2—Location of the Crossett Experimental Forest (CEF) and map of the research and demonstration areas.

INTRODUCTION

Restoration efforts are now one of the primary driving forces in national forest management and the research programs designed to support this policy (Bosworth and Brown 2007). For many, this is a radical departure from the traditions of forestry and silviculture, in large part because of the shift in emphasis from timber harvesting to management for a variety of benefits. In reality, the emphasis on restoration shares many of the original aims of forestry. As an example, silviculture was in part designed to rehabilitate degraded forest ecosystems and renew their commercial productivity and natural resilience (Pinchot 1947). Even though the ultimate objective (timber only versus multiple use) has changed considerably, our silvicultural toolkit can still serve us well in the contemporary management of public lands (Guldin and Graham 2007). Indeed, it is the many lessons we have learned on how to manipulate the forest to yield predictable and desirable outcome(s) that permits us to attempt to restore these systems.

The establishment and operation of the Crossett Experimental Forest (CEF) in southern Arkansas is a classic example of how the implementation of science-based forestry and silvicultural research was and can still be used to restore landscapes. By the early 20th Century, decades of exploitive logging and land clearing had devastated the virgin pine forests of the region (fig. 1). As the 1920s closed, some in the local timber industry recognized the potential of their lands to sustain productive second-growth pine forests, if they only knew what to do (Reynolds 1980). Even though operations such as the Crossett Lumber Company supported the research and extension efforts of distant university academics, their work was too limited to be of much practical use. Starting in the early 1930s, the Southern Forest Experiment Station of the U.S. Forest Service offered another possibility—the establishment of permanent experimental stations staffed by federal researchers to conduct long-term research and demonstration projects and help landowners manage their properties (Bragg 2005, Demmon 1942, Reynolds 1980).

It was into this environment that Russ Reynolds, a recent graduate of the University of Michigan, came to work with Ozark-Badger, Crossett, and other lumber companies. Reynolds helped carve the CEF out of the cutover landscapes of southern Arkansas (fig. 2). When established in 1934, the CEF offered a means to design, demonstrate, and monitor the long-term response of silvicultural treatments in loblolly (*Pinus taeda*) and shortleaf (*Pinus echinata*) pine-dominated forests (Reynolds 1980) on productive sites (SI50 = 85 to 90 feet). The CEF opened for "business" on January 1, 1934, and over the next few years, Reynolds installed a number of key long-term demonstration and research areas (Reynolds 1980). During the following decades, other research was established that either continued existing projects or addressed new questions based on changing markets, utilization, silvicultural strategies, and resource interests.

As the CEF enters its eighth decade of service, a number of these long-term studies (e.g., the Good and Poor Farm Forestry demonstration areas, Reynolds Research Natural Area (RRNA), Methods-of-Cut) have had many years of detailed observations, and the silvicultural lessons learned in their implementation, maintenance, and analysis continue to develop. In this paper, we describe how information gleaned from these long-term experiments and demonstrations can be adapted to questions arising from a new silvicultural direction—the restoration of stands with old-growth-like characteristics. Unlike some existing large-scale projects in the South (e.g., Stanturf et al. 2004), these lessons are more strategic than tactical because we are still in the process of adapting our knowledge of traditionally managed southern pine to produce both old-growth attributes and commodities.

Table 1—A sample of the desired standards and guidelines for successful restoration of old-growth-like conditions in loblolly and shortleaf pine stands of the UWGCP in southern Arkansas, adapted from Bragg (2004a)

Attribute	Reference target
Species composition	50 to 60 percent loblolly pine 35 to 45 percent shortleaf pine up to 10 percent hardwoods
Basal area	50 to 70 square feet per acre
Maximum tree DBH/age	unlimited
Number of big trees	5 to 15 pines > 30 inches d.b.h. per acre
Reserved timber volume	5,000 to 10,000 board feet (Doyle) per acre
Spatial pattern	patchy
Under/mid-story	open
Red heart	10 to 50 percent cull in retained trees
Large woody debris	5 to 10 snags (285 to 715 cubic feet) per acre

SILVICULTURAL CONTEXT

Repeated logging and conversion to other land uses over the last 150+ years have virtually eliminated old-growth loblolly and shortleaf pine-dominated forests that once covered much of the coastal plain of the southern United

States. Second-growth natural stands of mixed loblolly and shortleaf pine are still common, although none of them possess all of the attributes of their presettlement versions. Furthermore, naturally regenerated pine stands are under considerable pressure from commercial timber interests, land developers, and other threats to forest health (e.g., southern pine beetle (*Dendroctonus frontalis*)). For instance, although the generic "loblolly-shortleaf pine" cover type has held steady since the early 1950s at about 25 percent of the timberland in the southeastern United States, natural pine stands have declined from almost 72 million acres in 1952 to just under 33 million acres in 1999, with concurrent increases from 2 to 30 million acres of planted pine (Conner and Hartsell 2002).

There is growing interest in using silviculture to restore existing loblolly/shortleaf stands into old-growth-like conditions, especially from some national forests. A classical example of this interest is the pine-bluestem restoration project initiated in the 1990s on the Ouachita National Forest (Stanturf et al. 2004, U.S. Forest Service 1996). This large-scale project has been successful, spawning interest from other national forests desiring the same multiple-use results out of an integrated silviculture and restoration program. Success in one location, however, does not necessarily translate into acceptable results in other regions—there are enough unique attributes in any given landscape to require that every project be at least somewhat custom-designed. As an example, the management prescription for old-growth-like conditions in pine-dominated upland forests of the Upper West Gulf Coastal Plain (UWGCP) of southern Arkansas, northern Louisiana, southeastern Oklahoma, and northeastern Texas (Bragg 2004a) may not work in the shortleaf pine forests of the Ouachita or Ozark mountains, or even the hardwood-dominated forests of the UWGCP.

The successful restoration of old-growth-like forests requires the integration of historical information with lessons learned in places such as the CEF. Long-term silvicultural research and demonstration projects, some of which date back to the mid-1930s, can be modified into new strategies for multi-resource objectives. This paper provides examples taken from these projects on the CEF and related studies, and translates the lessons from conventional silvicultural treatments to the emulation of old-growth-like conditions. Ultimately, our prescriptive goal is not to reproduce an exact replica of a presettlement old-growth, but to incorporate as many of these key attributes as possible in a stand that is functionally self-supporting and actively managed.

WHAT ARE OLD-GROWTH-LIKE CONDITIONS?

Managing for old-growth-like conditions in the pine-dominated forests of the UWGCP refers to the encouragement of forest conditions dominated by features and processes akin to old forests of the presettlement (circa 19th Century) era. In other words, we aim to duplicate many of the same structural, compositional, and functional attributes of the virgin pine forests of the region (see fig. 1a) in contemporary stands still managed for some degree of commodity production. Rather than using a fixed set of narrowly defined criteria to judge success of this restoration effort, our standards and guidelines (table 1, see also Bragg 2004a) call for a range of conditions to be emulated using conventional silvicultural tools such as thinning, reproduction cutting, competition control, and even supplemental planting.

Unfortunately, we have only spotty information on what presettlement pine-dominated forests were like in the UWGCP. According to anecdotal reports, pines in excess of 40 inches d.b.h. (diameter breast height) or greater were common, and some individuals apparently exceeded 70 inches d.b.h. and over 5,000 board feet (unless otherwise specified, all board measures are Doyle scale) of lumber (Bragg 2002, 2003). These large trees, while very noticeable, were not so numerous that stand densities or sawtimber yields were particularly high. In a review of available information, Bragg (2002) noted that stand sawtimber volumes often ran between 5,000 and 20,000 board feet per acre, with most ranging between 10,000 and 15,000 board feet per acre. Annual growth data was even spottier, although some mature- to old-growth pine stands from southern Ashley County added between 50 and 120 board feet per acre per year (Chapman 1912, 1913). Size class patterns varied, but most exhibited at least a few pines across a broad range of diameters.

Hence, when compared to modern, managed examples of uneven-aged loblolly and shortleaf pine in the UWGCP, these virgin forests grew appreciably slower, contained greater volumes of sawtimber in (typically) larger trees, and probably had considerably fewer small stems. While intensively-managed uneven-aged pine stands contain dense pockets of regeneration and thus are not relatively open, it is likely that modifications to an uneven-aged prescription can be made to develop regeneration cohorts in a more episodic manner. It is possible that they could even be treated with prescribed fire. This would eventually produce a structural effect similar to that which is reported for virgin pine forests. Both of these would have relatively open canopies with multiple size classes distributed throughout the stand. Such a functional similarity would make it possible to emulate at least some aspects of old-growth-like forests while simultaneously supporting timber production (Bragg 2004a).

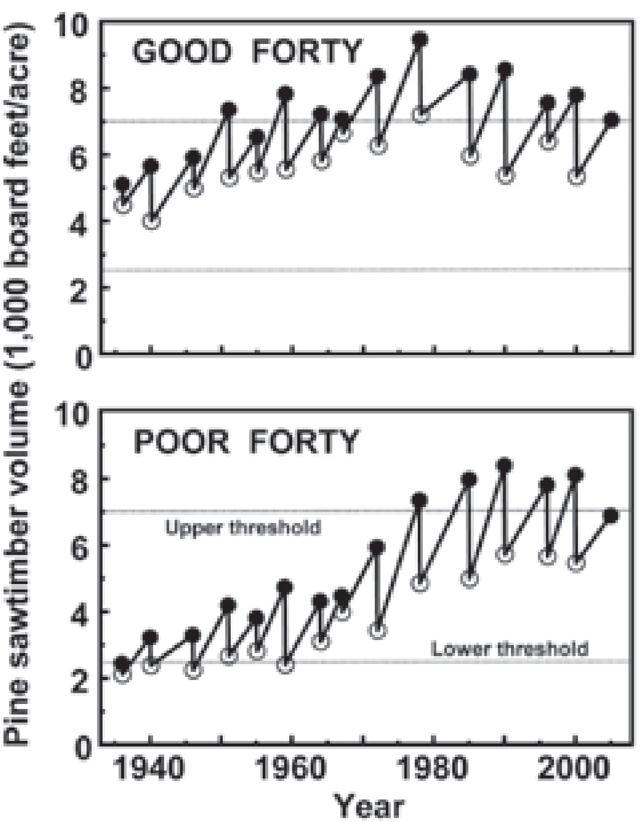

Figure 3—Pine sawtimber volume (Doyle scale) in the Good and Poor Farm Forestry Forties on the Crossett Experimental Forest (CEF) over a 69-year period. The filled symbols are before harvest and open symbols are after harvest. The dotted lines are the upper and lower stocking thresholds recommended by Baker et al. (1996). From Guldin (2002) and unpublished data on file at CEF.

UNEVEN-AGED MANAGEMENT AND RESTORATION SILVICULTURE

Loblolly and shortleaf pine forests can be managed under a number of different uneven-aged silvicultural methods, using either single-tree selection or group selection (Baker et al. 1996). The silvicultural key to making these methods successful involves maintaining a critical balance in stand stocking—a sufficient overstory is retained so that growth and yield continues at high rates, but this overstory is also periodically reduced to permit pine regeneration and canopy recruitment. In addition to the generation of quality pine sawtimber, uneven-aged silviculture supports many other non-timber resources. The structure and composition of mature, uneven-aged southern pine stands are considerably better for co-managing certain types of wildlife species. The Good Forty, for example, contains two active red-cockaded woodpecker (RCW) (***Picoides borealis***) clusters. The RCW has become an endangered species in large part because the older pines suitable for nest cavities have been largely eliminated in the younger, more intensively managed forests of the South (Conner et al. 2004a, 2004b). The loss of mature, open pine woods has greatly contributed to the decline of the RCW (Saenz et al. 2001).

The Good and Poor Farm Forestry Forties on the CEF have been successfully managed using uneven-aged silviculture with single-tree selection for 70 years. Some may find the success of uneven-aged silviculture in loblolly and shortleaf pine-dominated stands surprising, due to the relative shade-intolerance of these species. However, decades of demonstration work in the Good and Poor Farm Forestry Forties have shown the efficacy of this technique, given some adjustments for species autecology and local site conditions (Guldin 2002). During these years, our monitoring of these parcels has provided critical information about pine regeneration, structural and compositional stability, and resource sustainability capable of guiding prescriptions for old-growth-like pine forests.

The initially poorly stocked Poor Forty was established to show how stands could be rehabilitated using uneven-aged silviculture, while the better-stocked Good Forty was established to document rates of growth and yield once rehabilitation had been achieved. And grow they did! Long-term records (from 1936 to 2005) have shown annual growth averages about 400 board feet per acre

Figure 4—Contrasts in the structure and composition between the Good Forty (a) and the RRNA (b) are obvious when these stands on the Crossett Experimental Forest are compared.

in the Good and Poor Forties. Stocking was rapidly improved in the Poor Forty by harvesting less than growth, while the well-stocked condition in the Good Forty was essentially maintained by harvesting the periodic growth (fig. 3). These cuts, now done about once every 5 years, remove mostly mature, high-quality sawtimber. Harvests over this 69-year period totaled 24,000 board feet per acre in both the Good and Poor Forties. In addition, standing pine volume in 2005 was 50 to 200 percent greater than in 1936 (fig. 3). Throughout this period, the Good and Poor Forties retained a component of big trees, averaging 5 trees per acre with d.b.h. of 20 inches and larger before the periodic harvests.

THE HISTORICAL AGE STRUCTURE OF UNEVEN-AGED PINE STANDS

There is no reliable information on the age structure of presettlement forests of loblolly and shortleaf pine in the UWGCP. Few stands of old-growth pine or pine-hardwood timber remain, making it difficult to generalize using these remnants as models. However, if appropriately applied, some inferences can be made that have important silvicultural consequences. After examining recent stumps following salvage and limited increment coring, Bragg (2006) reported that the pine overstory in the Levi Wilcoxon Demonstration Forest (LWDF) in Ashley County, Arkansas, was uneven-aged. Overstory pines ranged from about 80 years old to as much as 300 years old, and were primarily recruited between 1800 and 1920. In a bottomland hardwood-loblolly pine stand in nearby Calhoun County, Heitzman et al. (2004) placed pine establishment during three primary periods: 1850-60; 1861-90; and 1981-90.

Hence, it appears that many (if not most) of the presettlement pine forests of the UWGCP were at least broadly uneven-aged, with periodic small- and large-scale distur-

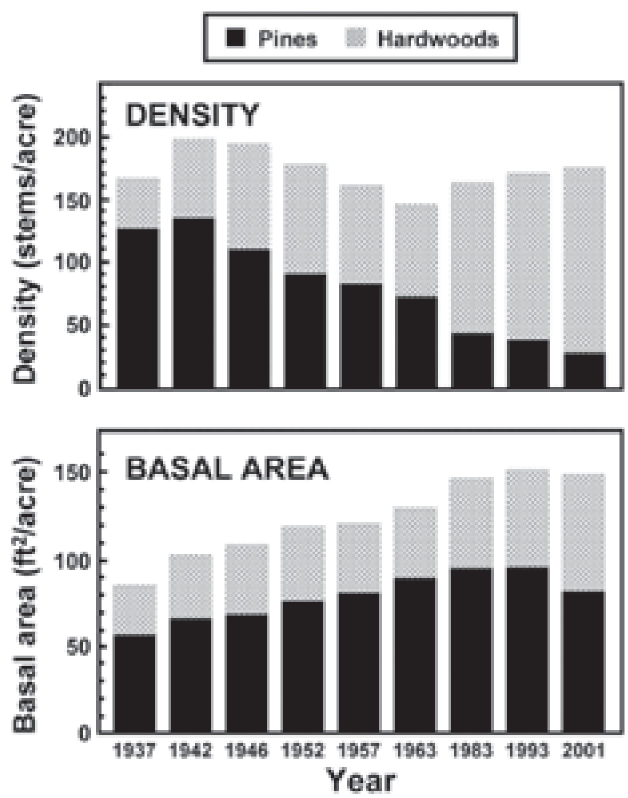

Figure 5—Successional changes in pines and hardwoods 4 inches d.b.h. and larger over a 64-year period in the Reynolds Research Natural Area on the Crossett Experimental Forest (CEF). Adapted from Cain and Shelton (1996) and updated with unpublished data on file at CEF.

bances allowing for the establishment of new cohorts of regeneration (Bragg 2006, Heitzman et al. 2004). This produced scattered individuals or patches of older “veteran” trees intermingled with more extensive areas of maturing timber (Bragg 2002). This pattern is consistent with stand maps made in southern Ashley County from Chapman (1912) that distributed large, decadent old pines in a matrix of maturing trees. Areas of even-aged stands arising from natural disturbances were also noted elsewhere in Arkansas (Turner 1935), and probably comprised a significant portion of the presettlement landscape. From a restoration perspective, this distribution implies that at least some degree of age variation should be present for old-growth-like conditions. This, in turn, suggests that the stands be treated in a manner capable of producing multiple age classes.

Even though fire was an important dynamic in the presettlement pine forests of the UWGCP, conventional wisdom holds that intensively managed uneven-aged pine stands are best managed without fire. However, work on the CEF has shown that fire can be compatible with uneven-aged mixed pine forests. A 19-year study of different burning regimes showed that, though not very efficient at producing large numbers of saplings, low- to moderate-frequency dormant season fires did not completely eliminate them from the treatment areas (Cain and Shelton 2002). Regularly applied dormant season fires were found to only temporarily suppress competing hardwoods, and the fires also killed much of the pine regeneration. Thus, the authors suggested that fires be applied in conjunction with herbicide use, which would allow pine regeneration to more quickly reach fire-tolerant size (Cain and Shelton 2002). Another adaptation using fires to control species composition in uneven-aged pine stands would involve an interrupted burning cycle. Repeated dormant season prescribed fires would be used to control competing hardwoods, but this burning cycle would be interrupted long enough for pine seedlings to become established and to grow to fire-tolerant sizes. After a brief interval, the burning cycle would then be reestablished (Cain and Shelton 2002).

Residual old trees are also important for the restoration of old-growth-like conditions. Unlike most pine plantations in the UWGCP, which are generally harvested after 30 to 35 years when the pines have just reached reasonable sawlog size, uneven-aged stands will frequently have trees greater than 70-years old, and often these trees are of considerable diameter and height (Guldin and Fitzpatrick 1991). The older component of uneven-aged pine stands often possesses a greater incidence of red heart fungus (***Phellinus pini***), an attribute critical to RCW nest cavity excavation (Conner 2004a, 2004b). Since the current managing for old-growth-like condition strategy calls for the retention of some of the oldest and largest pines regardless of how old they may be (Bragg 2004a), these trees provide attributes such as RCW cavities and aesthetics without excessively compromising fiber production.

LESSONS FROM UNMANAGED STANDS OF LOBLOLLY AND SHORTLEAF PINE

The dynamics and long-term composition of the RRNA have also taught us much about the behavior of unmanaged forests in the UWGCP. This research natural area, an 80-acre no-harvest reserve on the CEF, has been sheltered from fire and logging for over 70 years. When established, the RRNA was intended to showcase stand development in an unmanaged parcel compared to the adjacent managed Good Forty (fig. 4). The long-term dynamics of the RRNA have vastly differed from those of the Farm Forestry Forties. Even though some structural elements of the unmanaged RRNA are similar to the virgin forests of the region (for example, older pines, large quantities of dead wood), others are more comparable to managed stands.

For instance, after decades of stable stocking, net growth, and increasing yields, pine mortality rates in the RRNA have recently increased considerably, while growth has slowed and pine recruitment dropped to virtually nothing (fig. 5). Pine no longer dominates the overstory or understory composition of the RRNA, while the Farm Forestry Forties are heavily pine dominated in all age and size classes (figs. 4 and 5). This disparity is largely the result of lower over- and midstory density and the use of herbicides to control competing vegetation in the Farm Forestry Forties. Presettlement UWGCP forests typically had a variable and potentially significant component of hardwoods (Bragg 2002), but pine would have been very prominent, and its gradual disappearance in the RRNA does not bode well for the sustainability of conifers in this formerly pine-dominated tract.

Over the last half-decade, pine basal area in the RRNA and the nearby LWDF has continued to decline precipitously (Bragg 2006). Mortality is a natural component of any stand of timber, managed or otherwise, but it must be carefully regulated when restoring old-growth-like conditions so as not to lose the key overstory component that defines the type—pine. At times, preemptive harvests of pine beetle spots, storm damaged timber, or even large-scale salvage logging may be necessary to ensure that the overall health of the pine overstory is maintained. However, it is also important to ensure that at least some accumulation of dead wood is allowed, as this is a critical ecological attribute of old-growth (see later section).

Net pine growth in the first half of the 1990s became negative for the RRNA, with mortality losses double that of survivor growth and zero contribution from recruitment (Shelton and Cain 1999). While growth does not need to be maximized or optimized in a silvicultural strategy focused on restoring old-growth-like stand conditions, there is need for positive increment in at least some of the merchantable size classes. Presumably, the relatively open stand conditions and continual recruitment of young pines to the overstory will ensure that there is enough fiber production to support periodic harvests to regulate overstory density. The long-term regenerative success of the Farm Forestry Forties, coupled with their high-value sawtimber yield, suggest that it should be possible to maintain desired structures within these old-growth-like stands by encouraging vigorous smaller classes, even if mortality in the largest classes (retained for their contributions to stand structural complexity) is high at times.

RETAINING A PINE OVERSTORY VIA NATURAL REGENERATION

The failure of pines to replace themselves in the RRNA and the LWDF is a clear lesson on how not to perpetuate a pine-dominated canopy. Pine regeneration is a complicated process, involving the impacts of stand conditions, fire suppression, hardwood competition, and woody debris and duff accumulation. The presettlement pine-dominated forests were typically self-replacing, propagated by frequent fire and other large-scale, intense perturbations that produced adequate pine regeneration conditions while simultaneously restricting the success of competing hardwoods. For our old-growth restoration efforts to be successful, we must be

Table 2—Quantitative expression of some factors affecting the success of establishing pine regeneration and providing for its development in the Reynolds Research Natural Area (RRNA) and the Good Farm Forestry Forty on the Crossett Experimental Forest (CEF)

Factor[a]	RRNA	Good Forty
Mean seed production per acre	503,000	418,000
Median seed production per acre	60,000	195,000
Litter depth: inches	1.0	1.1
Light intensity near ground: percent of full sunlight	4	66
Pine basal area, trees ≥ 4 inches d.b.h.: ft^2/acre	82	63
Hardwood basal area, trees ≥ 4 inches d.b.h.: ft^2/acre	68	1

[a] Compiled from several published sources providing data and/or background information on methods (Cain and Shelton 1995, 2001; Guo and Shelton 1998; Shelton and Cain 1999) and unpublished data on file at CEF. Seed production was for 16 years (1991 through 2006); tree inventories were from 2000; litter depth was determined in 1994, about 4 years after the Good Forty was last harvested.

able to emulate this result without investing heavily in artificial regeneration or competition control. After all, low-cost, low-impact, self-replacing pine stands can produce both environmental complexity characteristic of presettlement old-growth and make it much easier to convince landowners to sustain their efforts over the long run.

First, to sustain the pine overstory for the foreseeable future, conditions must permit the recruitment to the canopy. For naturally regenerated pine stands, the key factors to ensure adequate regeneration include an ample seed supply, an acceptable seedbed, and sufficient amounts of limited resources such as light, water, and nutrients (Shelton and Cain 2000). Seed production and seedbed conditions generally affect the initial establishment of regeneration, while its subsequent development is largely determined by the amount of limited resources that are available to established seedlings. These regeneration factors are also under a varying level of silvicultural control. For example, both loblolly and shortleaf pine tend to experience a bumper seed crop, a seed crop failure, and three average seed crops during a 5-year period (Cain and Shelton 2001). Although silviculturists can do little to modify this natural variation, they can determine the number, size, vigor, and quality of the seed-producing trees that occupy the site. In contrast, seedbed conditions and the resources available to the species targeted in regeneration are more easily modified by tools such as site preparation, competition control, and harvesting.

Some of the factors that our silvicultural experiences have found to affect pine regeneration can be contrasted for the RRNA, where the pine component is not being sustained (Cain and Shelton 1996), and the adjacent Good Farm Forestry Forty, with its stable pine dominance. These differences did not arise from seed limitations. Pine seed production was ample in both areas (table 2). Historically, seed production in the unmanaged RRNA has exceeded that of the Good Forty by an average of about 25 percent. This difference was mainly due to exceptionally high production in the RRNA during bumper years. The effects of stand management are more apparent by considering the median value for seed production, where the Good Forty exceeded that of the RRNA by three times.

Table 3—Density of pine regeneration in the Reynolds Research Natural Area (RRNA) and Good Farm Forestry Forty on the Crossett Experimental Forest

	Seedlings[b]		Saplings	
Year[a]	RRNA	Good Forty	RRNA	Good Forty
	per acre		*per acre*	
1982	8[c]	1,210	0	80
1993	733	6,920	0	480
2001	110	825	0	239

[a] Sampling methods vary from sixty 0.002-acre subplots to one hundred 0.001-acre subplots.

[b] Seedlings have d.b.h. <1 inch; saplings have d.b.h. of 1 to 3 inches.

[c] Does not include seedlings <0.5 feet tall.

Likewise, seedbed conditions in the two areas also were found to be similar. Both areas consisted of a litter seedbed with a depth of about 1 inch (table 2). However, the litter depth reported for the Good Forty in table 2 was measured 4 years after the most recent harvest. Logging has both positive and negative effects on the germination of pine seeds. Harvesting creates favorable conditions by displacing forest floor litter and exposing mineral soil, but it also creates an unfavorable seedbed in certain areas covered by logging debris. Shelton and Cain (2000) reported that typical seedbed conditions following harvesting of the Good Forty was 40 percent undisturbed litter, 30 percent disturbed litter, 25 percent logging debris, and 5 percent exposed mineral soil.

The biggest difference in the conditions for regeneration between the RRNA and Good Forty was expressed in light levels near the ground, which averaged 4 percent of full sunlight in the RRNA compared to 66 percent in the Good Forty (table 2). Even though loblolly and shortleaf pine seedlings are moderately shade-tolerant during their first few years, seedlings become more intolerant to shade as they develop. Thus, the low light environment under the relatively continuous, dense canopy of the RRNA strongly limits pine regeneration. Pulses of pine seedlings can establish in the RRNA during years with high seedfall and ample summer moisture, but these seedlings die long before reaching sapling size (table 3). In contrast, pine canopy recruitment is continuous in the Good Forty, where enough seedlings grow into saplings and saplings grow into merchantable trees to sustain the pine overstory.

The favorable light environment for the overstory recruitment of pine was maintained in the Good Forty by periodic harvests and repeated control of non-pine competing vegetation, principally using selective herbicides. These silvicultural activities have virtually eliminated merchantable hardwoods in the Good Forty, while the RRNA in comparison had 68 square feet per acre of hardwood basal area (table 3). Due to their broad leaves and large crowns, hardwoods generate about twice the level of shade as do pines per unit of basal area (Guo and Shelton 1998), so the acceptable level of hardwoods dispersed amongst the pines is inherently low. A basic tenet regarding competition control is that as site quality increases, the aggressiveness of competition control must also increase (Shelton and Cain 2000).

In addition to its impact on pine regeneration, the dense hardwood under- and midstory of the RRNA has affected other ecosystem properties. Traditionally, uneven-aged stands have a much more open canopy structure than plantations because uneven-aged stands are managed at lower stocking levels. This openness, once prevalent in the presettlement landscapes, permits certain ecosystem attributes not possible in intensively managed stands. For instance, with some minor modifications to traditional uneven-aged practices (for example, retention of large red heart infected pines, reducing the density of the midstory near cavity trees), sustainable RCW clusters can be incorporated. While the RRNA contains some of these attributes (for example, widespread occurrence of red heart in large pines), there are no active nest clusters in this stand. Even though it can be argued that the perpetuation of the RCW clusters in the Good Forty has been made possible, in part, by the use of nest box inserts, without the open nature of the uneven-aged stands of the CEF, these clusters would not have been able to persist.

Because management for old-growth-like conditions in pine-dominated forests implies the direct manipulation of the physical environment, there is considerable flexibility in how regeneration is achieved. As an example, the successful regeneration of pine in the Good Forty involves regulation of the overstory pine through volume-guided harvests typically conducted about every 5 years. Ideally, harvests are scheduled so that the volume in merchantable trees does not exceed 7,000 board feet per acre, which is the observed threshold level at which the overstory competition begins to unacceptably suppress recruitment (Baker et al. 1996). Without the ability to recruit new pines to the canopy, any uneven-aged silvicultural system intended to perpetuate a pine overstory would quickly fail. Harvesting, seedbed disturbance, and chemical and/or fire-based competition control are necessary to ensure viable pine recruitment. Even supplemental planting may prove to be the best strategy under certain conditions.

DEAD WOOD MANAGEMENT

Overstory attrition, whether in intensively managed seed-tree or uneven-aged stands or unmanaged old-growth, is a continual process. Under most circumstances, large crop trees are very exposed, and hence particularly susceptible to mortality agents such as ice storms, lightning, or windthrow. Losses to bark beetles and other insect pests, disease, wildfire, and logging damage further reduce the number of canopy pines that must eventually be replaced. While it is possible to mitigate these losses with well-planned harvest entries, salvage of dead or declining trees, and other protective techniques, there is no way to eliminate tree mortality.

To some degree, mortality losses are more than just a cost of doing business, they are an ecological necessity. For instance, without dead trees (or the loss of large parts of live trees), it is impossible to accumulate coarse woody debris (CWD), a critical habitat element that serves many vital ecosystem functions (Harmon et al. 1986, Spetich et al. 1999, Van Lear 1996). CWD volumes tend to be higher in unmanaged forests. When last measured, the RRNA exceeded 1,700 cubic feet per acre of CWD, compared to 470 cubic feet per acre in the occasionally salvaged LWDF and only 214 cubic feet per acre in managed stands on the CEF (Bragg 2004b, Zhang 2000). Conceivably, an intensively cultured stand with continual salvage and high rates of product utilization may have almost no CWD. This is a desirable outcome when fiber production is the primary goal, but an unwanted simplification when managing for old-growth-like conditions (Harmon et al. 1986, Spetich et al. 1999).

In the end, a stand managed for old-growth-like conditions needs to retain a large quantity of CWD—perhaps not to the extent seen in the RRNA, but more than that found in conventionally managed stands of mature pine timber. Salvage operations to remove dead and dying trees should be limited to circumstances where either an insect or disease outbreak threatens management objectives, or where safety factors override environmental goals (for example, along roads, trails, campsites, near buildings). Otherwise, moribund trees should be left to expire on their own accord. Snags should be allowed to accumulate and fall. The less than complete utilization of all the trees on these sites is not necessarily a bad thing.

ANTICIPATED CHALLENGES

Even though we expect this silvicultural system to work, a number of challenges in its implementation and long-term success are expected. Certainly, total fiber and sawlog volume production will be lower under this strategy when compared to more conventional treatments such as uneven-aged silviculture. Logistical issues will also arise. For instance, marking the appropriate pines for removal in harvests will take additional training to ensure that the desired ecosystem attributes are retained. We also expect there to be some difficulty in getting loggers to harvest the stands without excessively damaging some of the residual trees and the pine regeneration, as most are no longer accustomed to cutting uneven-aged stands.

While these challenges can be addressed through additional training and discussions (coupled with close monitoring), other factors are harder to control and may require modifications to management strategies over time. As an example, shortleaf pine is noticeably harder to regenerate than loblolly on the UWGCP. This tendency is likely due to long-term decreases in shortleaf pine overstory density from discriminatory harvesting and shifts in disturbance regimes from one driven by fire (favoring shortleaf) to one influenced primarily by logging and land clearing, which favors the reproductive proclivity of loblolly. Hence, it may be necessary to facilitate shortleaf pine during the canopy recruitment stages of stand development by discriminating against loblolly. Even this may still not produce the desired outcome of significantly greater shortleaf canopy representation.

CONCLUSIONS

Using these lessons, we believe the productive potential and resilience of mixed loblolly/shortleaf pine forests can be adapted to create functional examples of old-growth-like stands capable of sustainably producing both timber and non-timber outputs. Although considered shade-intolerant, both loblolly and shortleaf pine possess characteristics that make them conducive to the creation and maintenance of old-growth-like conditions. These include their moderately long-lived nature, adaptations for fire, rapid growth on a wide range of soils and sites, favorable timber characteristics, an ability to recover well from logging and weather damage, response to release following suppression, and the ease in which loblolly and shortleaf pine regeneration is secured. Fortunately, our conventional silvicultural tools are exactly the instruments of change required to take advantage of these characteristics.

In addition to the conduciveness of the primary overstory species involved, there are less direct lessons from our long-term silvicultural research that can be adapted for more successful restoration projects. For instance, we have found that managing for a particular ecosystem element, such as the stand openness required to regenerate a pine overstory in uneven-aged stands, also encourages structural and compositional characteristics that can contribute desirable habitat for wildlife species (Conner et al. 2002, Thill et al. 2004). Translated to old-growth-like stand management, this suggests that more of the physical and biotic environments will be restored, furthering the value of the ecological rehabilitation of the landscape.

A tentative blueprint for the implementation of restoration silviculture in pine-dominated forests in the UWGCP proposes to use a combination of timber harvesting, competition control, and adaptive management to restore existing stands into a similar composition, structure, and dynamics as the old-growth stands that once characterized the region (Bragg 2004a). Any such design would not have been possible without the decades of long-term experiments and demonstrations to illustrate how these forests behave under certain controlled conditions. This is a powerful argument for the continuation of the use of experimental forests and long-term projects in the U.S. Forest Service's research and development program.

ACKNOWLEDGMENTS

We would like to recognize the efforts of all of the scientists and staff (past and present) at the Crossett Experimental Forest whose work made this paper possible. In particular, we would like to thank Jim Baker, Michael Cain, Mike Chain, and Kirby Sneed. O.H. "Doogie" Darling also helped with his information on the history of the Crossett Lumber Company. Tom Crow, Nancy Koerth, Norm Michaels, Jamie Schuler, and Lynne Thompson graciously provided reviews of this manuscript.

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