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silviculture

The Silvicultural Implications of Age Patterns in Two Southern Pine Stands After 72 Years of Uneven-Aged Management

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A randomized sample of 250 loblolly (*Pinus taeda* L.) and shortleaf (*Pinus echinata* Mill.) pine ring counts was collected from the Good and Poor Farm Forestry compartments on the Crossett Experimental Forest. These mature, pine-dominated stands have been managed using uneven-aged silviculture since 1937. Our sample shows that both of these compartments have many different age classes although few distinct cohorts. Over the decades, pine recruitment followed the dozens of timber harvests and occasional natural mortality events (e.g., lightning strikes, ice storms, windthrow, insects, and disease). After more than 70 years of active management, only 5% of the overstory pines are shortleaf and about 6% of all pines originated before the imposition of uneven-aged silviculture. The age structure of these stands can be used to adapt conventional silvicultural treatments. For example, a wide range of ages was found in the sawtimber size classes, indicating that productivity improvements are still possible. The data also suggest that it may be possible to modify current practices to alter the age structure to favor other kinds of ecosystem services (e.g., wildlife habitat).

Keywords: Crossett Experimental Forest, loblolly, shortleaf, stand structure

Encouraging sound timber management by nonindustrial private landowners has long been a goal of foresters, particularly in parts of the southeastern United States plagued by overcutting, overgrazing, erosion, and other abusive practices (e.g., Westveld and Peck 1941). Translating technical research for these landowners proved to be a daunting challenge; in response, "Farm Forestry" demonstrations were established on a number of experimental forests. Usually about 40 acres in size, these stands were intended to show small landowners (usually farmers) how to effectively use good silvicultural practices to supplement their income (Reynolds 1980, Baker and Bishop 1986). Today, many of these demonstrations are still managed following their original prescriptions; for instance, the "Farm 40" on the Escambia Experimental Forest (Brewton, AL) continues to yield longleaf pine (*Pinus palustris* Mill.) poles and sawtimber more than 60 years after the demonstration began (Barlow et al. 2011).

Established by pioneering silviculturist Russell R. Reynolds in 1937, the loblolly (*Pinus taeda* L.) and shortleaf (*Pinus echinata* Mill.) pine-dominated stands of the Farm Forestry Forties on the Crossett Experimental Forest (CEF) likewise produce commercially viable quantities of high-quality sawlogs after decades of continuous treatment (Reynolds 1969, Reynolds et al. 1984, Guldin 2002). The "Good" and "Poor" Farm Forestry Forties[1] are two approximately 40-acre parcels named for their initial stocking conditions (not site quality). These stands have been managed with a type of uneven-aged regulation called "volume guiding diameter-limit" (VGDL), an adaptation of Biolley's original approach (as described in Knuchel [1946]) in which the allowable cut essentially equals periodic annual growth (Reynolds 1959). Timber marking in VGDL is typically limited to larger stems (≥11.6 in. dbh) and follows the principle of cutting the lowest quality (or least likely to survive) trees and leaving the best (Reynolds 1969, Reynolds et al. 1984, Baker et al. 1996, Farrar 1996). Over the decades, seedbed preparation has been limited to soil disturbance associated with logging, and some chemical and mechanical competition control has been done. This suite of treatments has produced a fairly constant growth of approximately 350–400 bd ft/acre of pine sawtimber[2] while ensuring nearly continuous pine establishment and canopy recruitment in these compartments since the late 1930s (Guldin and Baker 1998).

From this brief description alone, it would appear self-evident that the CEF Farm Forties are multiaged. Yet, there have never been

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any formal studies of the age structure of these otherwise well-documented stands. Visitors to the CEF often inquire whether the structure of these compartments has resulted from frequent recruitment or only occasional new age cohorts. Better knowledge of the age distribution of the Farm Forties after decades of intervention should also provide insights into the long-term sustainability of uneven-aged management in shade-intolerant conifer species and new information on the development of structurally viable conditions (e.g., O'Hara 1998). In addition, the silviculturally mediated alteration of southern pine forests, particularly in the face of climate change, shifts in landownership, and evolving landowner and ecosystem service priorities, requires a more complete understanding of the interaction of management decisions with forest health and productivity as a function of tree age.

Methods

Stand Descriptions and Land Use History

The CEF is located in the Upper West Gulf Coastal Plain of Arkansas, about 7 miles south of the city of Crossett in Ashley County. The Farm Forties are located in the southern portion of the CEF and are approximately 130 ft above mean sea level. There is limited variation in elevation across the experimental forest, with local relief rarely exceeding 6 ft and only a handful of small, ephemeral streams that drain the gently undulating land surface. Soils are primarily silt loams that developed in a layer of loess up to 3-ft thick; low, naturally formed "pimple" mounds are also abundant. Annual precipitation averages about 55 in., and there is a 240-day growing season; combined with the previously mentioned edaphic conditions, the moderately productive CEF has 50-year loblolly pine site indices of 85–95 ft (Cain and Shelton 1996).

Before Euroamerican settlement, the virgin forests of the CEF were dominated by open stands of loblolly and shortleaf pine with limited quantities of hardwoods (Chapman 1913, Reynolds et al. 1984, Bragg 2003). Locally, some subsistence farming occurred during the late 19th and early 20th centuries, and the Gulledge Brothers and Crossett lumber companies cut the virgin timber between 1910 and 1920 (Bragg 2012). Following this lumbering, no deliberate forest management occurred until after the property was acquired by the Southern Forest Experiment Station of the US Department of Agriculture Forest Service (Reynolds 1980, Guldin 2002). Immediately after its opening in 1934, the CEF was subdivided into 42 approximately 40-acre compartments, followed by a preliminary timber inventory and the installation of numerous research and demonstration areas (Reynolds 1980, Bragg 2012).

When established in 1937, the Good Forty (with 5,074 bd ft/acre) was considered well stocked, whereas the Poor Forty (at 2,340 bd ft/acre) was deemed poorly stocked (Reynolds et al. 1984). The first harvest on the Good Forty was done in 1938 and removed slightly less than annual growth to allow a gradual increase in stocking. Harvesting on the Poor Forty started in 1939, with an initial cut of about half the annual growth to accelerate the accumulation of growing stock. Stocking on the Poor Forty reached the preliminary target (~4,000 bd ft/ac) in 14 years; afterward, harvests were made comparable to those on the Good Forty. Between 1937 and 1968 (inclusive), 30 and 29 harvests were made on the Good and Poor Forties, respectively (Reynolds et al. 1984, Baker 1986). Before 1952, hardwood control in these compartments consisted of cutting and/or girdling all merchantable competitors, and between 1957 and 1961 hardwoods ≥1 in dbh were injected with 2,4,5-trichlorophenoxyacetic acid (Reynolds 1969).

Since the last annual cut in 1968, changes in silvicultural and logging practices have resulted in these stands being periodically entered. Reynolds retired in 1969 and although some staff remained into the early 1970s, the CEF was operationally closed from 1969 to 1978, with the exception of a 1973 cutting cycle harvest conducted by the University of Arkansas at Monticello. Management of the Farm Forties by Forest Service scientists resumed when the CEF reopened in 1978, but by then these stands had grown to nearly 90 ft^2/acre of basal area. It required some effort to return the Farm Forties to the desired structure. A conservative harvest and mechanical competition control were done in 1978, followed by entries in 1981, 1985, 1990, 1996, 2000, 2002, and 2011 and herbicide treatments in 1986, 1989, 1998, and 2003. Although no longer cut annually, the Farm Forties are still marked with Reynolds' version of the VGDL.

Increment Core Sampling

To sample loblolly and shortleaf pines from the Farm Forties, in the late summer of 2009 five 66-ft radius plots were placed every 264 ft on each of five evenly spaced transects starting along the southern boundary of both compartments (Figure 1). One understory (between 0.2 and 3.4 in. dbh, inclusive) and four overstory (at least 3.5 in. dbh) pines per plot were sampled. For the overstory trees, the following randomization was used: the first pine east of magnetic north was aged, followed by the first overstory pine south of east, then the first overstory pine west of south, and finally the first overstory pine north of west (Figure 1). The closest understory pine to plot center was then chosen, producing a sample of 25 understory and 100 overstory pines for each compartment. All selected pines were identified to species and had their dbh measured with a metal tape or small calipers.

Pines at least 2.5 in. in dbh were bored at 20 in. above the ground surface using an increment corer and examined to ensure that they were no more than two rings from the pith. Increment cores were stored in plastic straws in the field and then transferred to paper envelopes in the laboratory. Once dry, they were mounted in a grooved wooden block and sanded with increasingly fine sandpaper (from 100–400 grit) until the rings were obvious. Pines of <2.5 in. dbh were destructively sampled with a saw; they were cut at 20 in. above the ground surface and then cut flush to the ground, with the bolt returned to the laboratory for further processing (drying, sanding, and ring counting of both ends). The difference in ring count between the ends was used to estimate how long a pine took to reach 20 in. in height. This difference was then added to every ring count for the cored pines (those at least 2.5 in. dbh) to get a better estimate of stem age. No cross-dating of rings was attempted, so our data represent approximations of true age. However, given the relative clarity of the annual rings of these pine species, we believe they are accurate to within 2 years.

Size and Species Distributions

To prepare for the most recent (2011) cutting cycle harvest, a 100% tally of all merchantable-sized (>3.5 in. dbh) stems was taken of the Farm Forties in 2008 and then projected forward. Species information was not collected, so it was not possible to identify the exact proportions of loblolly and shortleaf pines from this inventory. Therefore, we used the loblolly and shortleaf pine fractions from the age sample taken in 2009 as a proxy. Hardwoods were also not identified to species in the 2008 inventory, but a number are found

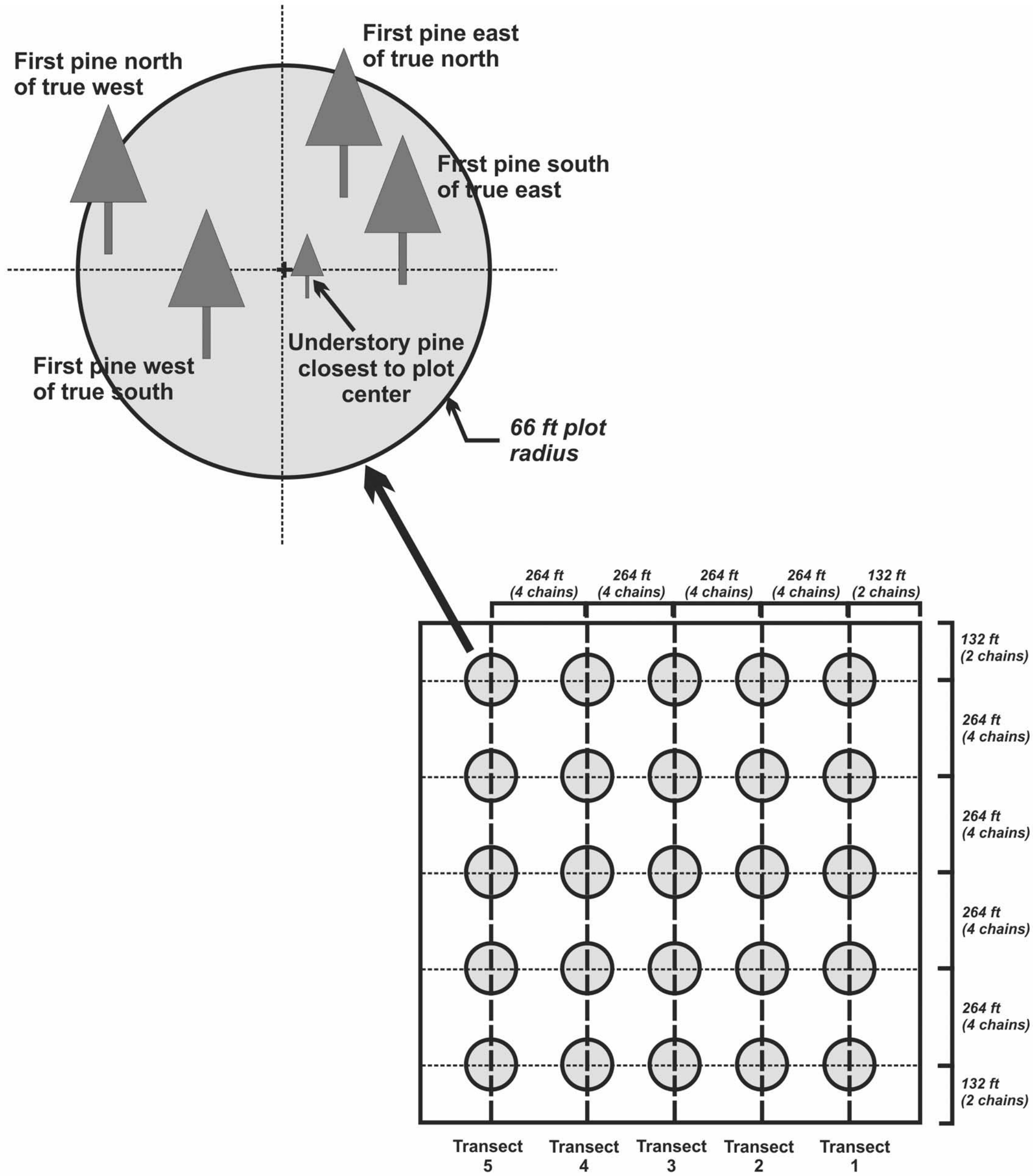

Figure 1. Sample pattern for this study showing how pines chosen for ring counts were randomly located from a systematic grid of plots.

in the Farm Forties, including water oak (*Quercus nigra* L.), sweetgum (*Liquidambar styraciflua* L.), American holly (*Ilex opaca* Ait.), and red maple (*Acer rubrum* L.).

Results and Discussion

After more than 70 years of active management, the Farm Forties still retain the desired characteristics of uneven-aged southern pine stands. Both compartments are appropriately stocked (basal area between 65 and 70 ft^2/acre) at this stage in their cutting cycle for stands dominated by shade-intolerant species (sensu Guldin and Baker 1998), with a reasonably well-distributed diameter structure (Table 1; Figure 2). To this end, the stands meet the simple field test of having foliage of the desired species present at all levels of the canopy profile. Today, the Farm Forties are remarkably similar in a number of attributes, including overstory stocking, basal area, biomass, and yield (Table 1). For example, in 2008 they differed by $<$2% in the board foot sawtimber yields, between 3 and 4% in total merchantable yields, and about 1.5% in total live tree biomass.

Stand Composition and Structure

Loblolly is the most dominant pine in both compartments; of the merchantable-sized pines aged on the Good and Poor Farm Forties, only 4 and 6% were shortleaf, respectively. Historically, shortleaf pine was considerably more dominant in this part of the Upper West Gulf Coastal Plain than it is today; Chapman (1913) described the virgin upland forests of southern Ashley County as an equal mixture of shortleaf and loblolly pine, consistent with a later statement by Reynolds (1959, p. 5) that in northern Louisiana and southern Arkansas the proportion was "… often half loblolly and half shortleaf." Reynolds also labeled these stands as "shortleaf-loblolly" in some of his early publications (e.g., Reynolds 1947), suggesting he may have then considered shortleaf the dominant pine. Second-growth stands that developed after the original lumbering of the

Table 1. Stand conditions for the Farm Forestry Forties on the Crossett Experimental Forest after 72 years of uneven-aged silviculture.

Attribute	Good Forty	Poor Forty
Stand size (acre)	39.4	33.1
Pines per acre	95.1	93.1
Hardwoods per acre	9.9	7.1
Total number of trees per acre	105.0	100.2
Pine basal area (ft^2/acre)	66.4	68.4
Hardwood basal area (ft^2/acre)	2.3	1.7
Total basal area (ft^2/acre)	68.7	70.1
Pine sawtimber yield (board feet/acre, Doyle log rule)*	8,189	8,325
Pine sawtimber yield (board feet/acre, international 1/4-in. log rule)	15,533	15,921
Pine sawtimber yield (ft^3/acre)	1,510	1,558
Total merchantable pine yield (ft^3/acre)	1,933	2,000
Pine aboveground live biomass (tons/acre)†	34.4	35.2
Hardwood aboveground live biomass (tons/acre)	1.5	1.1
Total aboveground live biomass (tons/acre)	35.8	36.4
Pine belowground live biomass (tons/acre)	8.8	9.0
Hardwood belowground live biomass (tons/acre)	0.4	0.3
Total belowground live biomass (tons/acre)	9.2	9.4
Total live tree biomass (tons/acre)	45.1	45.7
Maximum pine dbh class (in.)	27	26
Maximum pine ring count sampled (years)	96	86
Proportion of pines at least 72 years old (%)‡	5	7

Before this study, stands were last harvested in 2002–2003; inventory information is from 100% cruise of all live trees >3.5 in. dbh in 2008 and the tree ring count data from the sample collected in 2009.

* All sawtimber and merchantable volume yields were adapted from Farrar et al. (1984).

† All biomass in terms of oven-dry weights: aboveground live tree oven-dry biomass was calculated using the National Biomass Estimators of Jenkins et al. (2003), and belowground live tree oven-dry biomass was calculated following Enquist and Niklas (2002).

‡ Of all sampled pines at least 3.5 in. dbh (100 trees/compartment).

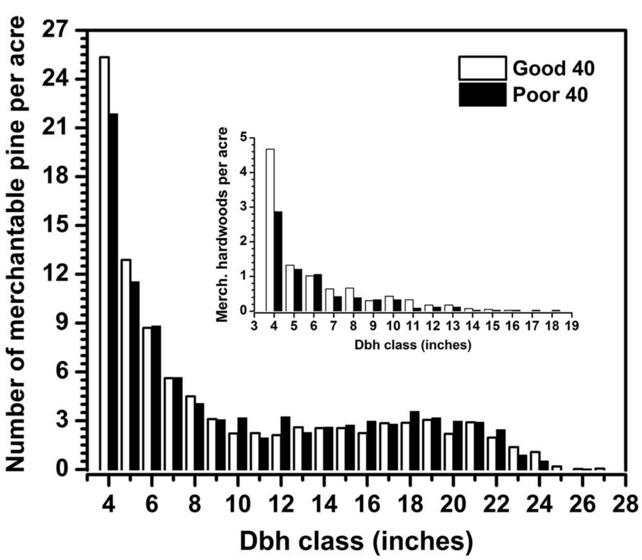

Figure 2. Diameter class distribution of tree species on the Good and Poor Farm Forties, from a 100% inventory of these compartments completed in 2008.

CEF had a noticeably lower yet still appreciable shortleaf pine component: approximately 10% of the merchantable basal area of the nearby Reynolds Research Natural Area was shortleaf pine in 1991 (Bragg and Shelton 2011).

The low shortleaf fraction in the Farm Forties is not surprising, given a general preference by foresters for the faster growing and

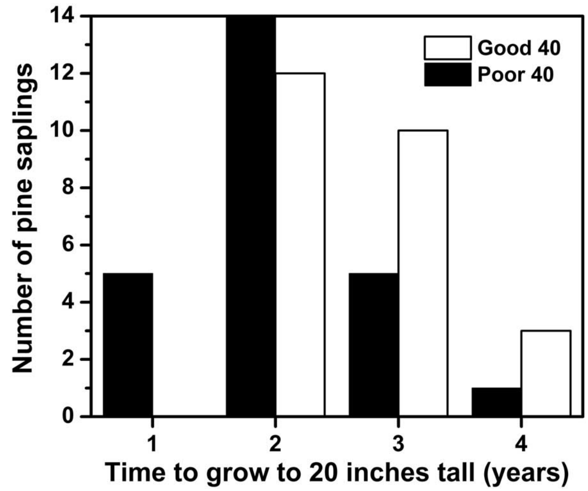

Figure 3. Number of years it takes pine saplings in the uneven-aged Good and Poor Farm Forties to grow to 20 in. tall, determined by subtracting the ring count for destructively sampled stems cut at groundline and 20 in. above groundline.

easier to regenerate loblolly. Shortleaf pine on the Gulf Coastal Plain tends to fare poorly in undisturbed conditions (it is now only 4.5% of the overstory basal area in the Reynolds Research Natural Area, compared with the approximately 50% loblolly that has remained at over the last 20 years). Very little prescribed burning was done on the CEF from 1937 to 1968, primarily because Reynolds did not favor its use, especially in uneven-aged stands (Reynolds 1980). The absence of fire has probably significantly lessened the abundance of the more fire-tolerant shortleaf pine on these mesic sites, given the ability of young shortleaf to readily resprout after top-killing surface burns (Mattoon 1908, 1915). Other examples of mixed pine and pine/hardwood stands in the region with a substantial history of fire tend to have a considerably higher proportion of shortleaf pine (e.g., Collins et al. 2006, Surrette et al. 2008, MacRoberts and MacRoberts 2009).

In 2008, the largest pines in the Farm Forties were in the 26- to 27-in. dbh classes (Table 1), and both stands displayed the reverse-J shaped/rotated sigmoidal diameter distribution expected in uneven-aged stands (Figure 2). Over time, size class structure on the Farm Forties has fluctuated, with an increasing quantity of large-diameter trees and noticeably fewer small-diameter stems (Guldin 2002). Since the last timber harvests in these compartments in 2002–2003, the uneven-aged diameter structure has improved, with several times more pines in the smallest size classes than reported by Guldin (2002). However, an excess of sawtimber remained in 2008, especially in stems >16 in. dbh (Figure 2). Hardwoods remain a minor component of the overstory in the Farm Forties (Figure 2, inset).

Age Distribution

Although there was some variability (Figure 3), on average it took seedling pines two growing seasons to grow to 20 in. tall. Thus, we added 2 years to the ring counts of all overstory pines. Very few pines date to before the formal imposition of silvicultural regulation; of the 200 overstory trees aged, only 12 (6%) had ring counts to 1937 or before (Figure 4). The oldest sampled individuals in the Good and Poor Farm Forties were 96 and 86 years old, respectively. According to the best records available, the Crossett Lumber Company cut the original forest on the Crossett Experimental Forest between

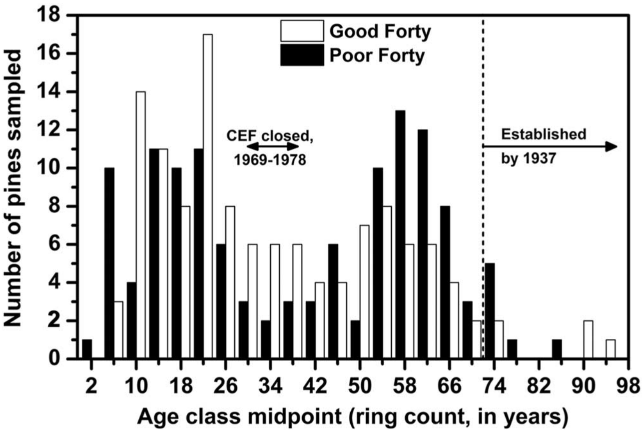

Figure 4. Pine ring count sample distribution as a function of age class midpoint from the Good and Poor Farm Forties, including certain key events in the history of these compartments.

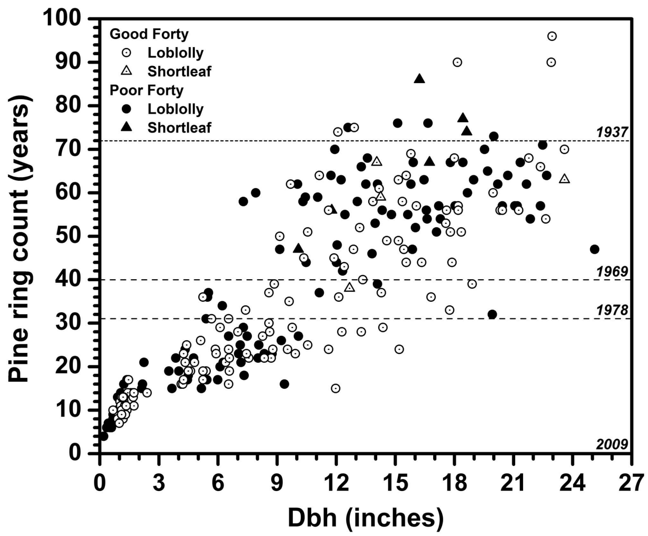

Figure 5. Age versus size distribution of the different pine species in the Good and Poor Farm Forties. The increment cores were taken in 2009. The Farm Forestry study began in 1937, and the CEF was temporarily closed from 1969 to 1978. The gap in the size distribution between 2.5 and 3.5 in. dbh appears to be more of a sampling anomaly rather than a true absence of trees this size. The wide dispersion of ages for a given dbh class suggests silvicultural opportunities depending on overall management goals for uneven-aged southern pine stands.

1917 and 1919 (Darling and Bragg 2008). Therefore, these oldest pines were present as advanced regeneration in the late 1930s.

The bimodal nature of Figure 4 suggests two major periods when trees were recruited: first, a peak in the 25 years after stand management began (especially in the Poor Forty), and the second in the period 1982–2002, as the stands recovered from the overstocking and subsequent adjustment cuts after the temporary CEF closure in 1969–1978. The complete absence of younger (<35 years old) shortleaf pine in Figure 5 is probably not accurate, because the sampling was not designed to inventory the species composition of all size classes. However, such scarcity is consistent with observations of a regional decline in shortleaf pine outside of the Ouachita Mountains of Arkansas and Oklahoma, especially in landscapes managed for timber without prescribed fire (e.g., Moser et al. 2007, Oswalt 2012).

As of 2009, both Farm Forties had a substantial quantity of trees between 50 and 70 years old (Figure 4). These individuals germinated during the first two decades of this demonstration and received regular competition control by both mechanical and chemical means (Baker 1986). Fewer pines date to between 25 and 50 years ago. One period in particular, from Reynolds' retirement in 1969 through the closing of the CEF in the 1970s until satisfactory harvests were reinstated in 1981, shows a prolonged period of reduced pine recruitment, especially in the Poor Forty (Figure 4). Most of this reduction can be attributed to excessive overstory density during the CEF's closure, growing levels of competition with hardwoods, an ice storm in the winter of 1971, and damage from a tornado in the spring of 1972 (Reynolds et al. 1984).

Discrete age classes are not apparent in these data. Given that from 1937 until 1968, Reynolds conducted annual harvests of these stands (Baker 1986), it is not surprising that neither stand has obvious cohorts in the older classes. After Reynolds' retirement, the Farm Forties were put on a periodic harvest regime, with a typical cutting cycle length of 5–7 years (Guldin 2002). However, the last three decades of episodic harvesting do not seem to have produced discrete cohorts, either (Figure 4). This result is probably the combination of several factors. First, over the past 30 years, the basal areas of these stands have generally been kept at between 60 ft^2/acre (immediately postharvest) and 75 ft^2/acre (at harvest), with the residual overstory distributed somewhat heterogeneously across the stands. This results in enough growing space in the understory to permit seedling establishment when conditions permit. Second, freshly cut sites tend to have favorable pine seedbeds for 2–3 years, thereby spreading out when seedling establishment occurs. Finally, the use of chemical competition control several years after harvest permits additional recruitment of new seedlings while enhancing the survival and growth of established saplings.

Size Versus Age Distribution

As found in many uneven-aged stands, there is a weak relationship between pine age and diameter in the Farm Forties (Figure 5). Up to about 15 years of age, the trend is well constrained, with only modest differences between trees of similar diameter. After this point, though, a considerably broader range appears. Pines of 25 years in age can be anywhere from 4 to 15 in. dbh, a spread that increases only slightly over the decades. Much of this diameter lag occurs before small-diameter trees are released from competition with the sawtimber-sized individuals in the overstory. Unless apical dominance has been lost and too little crown remains on these small pines, suppressed pines show a remarkable ability to respond to release and can quickly ascend into gaps in the canopy (Baker and Shelton 1998). Once in the canopy, the relatively low stocking of the overstory permits the development of large, full crowns over the course of decades, a better representation of free-to-grow circumstances than experienced after infrequent but heavy thinning in even-aged stands.

Silvicultural Implications

Our results point to an obvious conclusion: that more than 70 years of good uneven-aged silviculture in loblolly/shortleaf pine-dominated forests produces all-aged stands with adequate structure to support this system well into the future. Less apparent is how knowledge of existing age and size relationships can be used to refine this management regime. For canopy dominants, individual stem increment in these uneven-aged stands is usually excellent, especially when they have been well-tended and localized areas of competition-based growth suppression are rare (Reynolds et al. 1984, Baker et al. 1996, Guldin 2011). The large crowns of these dominant pines provide an ample source of carbohydrates to support both tree growth and seed production, which has been documented by long-term research as particularly reliable in the uneven-aged management areas on the CEF (Cain and Shelton 2001). High log quality is maintained by ensuring that most pine regeneration occurs in small, dense patches that promote early branch pruning; crop trees eventually get released through density-dependent mortality, logging damage to competitors, and/or thinning, allowing for the simultaneous development of big crowns and a long, clear bole (Reynolds 1959, Guldin and Fitzpatrick 1991).

A challenge to sustaining uneven-aged loblolly and shortleaf pine-dominated stands is determining the proper balance between adequate stocking to support sawtimber growth and volume development and sufficient direct and diffuse light in the understory to ensure new pine establishment, survival, and height growth. In these productive Upper West Gulf Coastal Plain sites, a residual stand basal area of 60 ft^2/acre after the cutting cycle harvest with 75% of that in the sawtimber component is ideal to maintain annual basal area and volume growth of 3 ft^2/acre and nearly 400 bd ft/acre, respectively (Baker et al. 1996, Guldin and Baker 1998, Guldin 2011). However, basal area levels greater than 80 ft^2/acre begin to suppress understory development, as occurred during the period when the CEF was closed. A key, then, is a commitment to regular harvests every 5–7 years followed by effective competition control, recognizing that frequent logging operations result in extensive vehicular traffic, which can damage the residual stand. Concentrating harvests to more limited areas and reducing or directing travel between eligible trees should help minimize logging-related damage.

With this background, silvicultural opportunities can be inferred from the wide range of tree ages noted for merchantable pines in this study. If optimizing growth and yield is the driving factor behind the uneven-aged management of a given stand, targeting low-performance individuals for removal early in the process should allow for better use of canopy space, thereby making stand-level production more efficient. Pines with early performance issues, whether excessively suppressed, diseased, damaged, or genetically inferior, experience lags in their diameter increment that are often perpetuated throughout the life of the tree. This was the reason Reynolds was a strong advocate of cutting the worst and leaving the best pines. Hence, recognizing the indicators of slow growth in trees in the large pulpwood and small sawtimber classes (e.g., lack of apical dominance, limited crown extent, smooth bark, and evidence of disease) is a critical skill for production-related uneven-aged silviculture. As implemented, the VGDL regulation method operates primarily in the sawlog component, with little to no marking of pulpwood outside of the guidelines to maintain thrifty stands. There are financial reasons for this avoidance: until recently, sawtimber has been worth several times the stumpage price of pulpwood in this part of the South (Guldin and Guldin 1990). However, when the value per unit volume of sawlogs is comparable to that of pulpwood, a more aggressive approach to thinning in smaller diameter classes may be justified.

Of course, removing slow-growing individuals, especially in the largest dbh classes, could have impacts on other ecosystem services. If the primary management goal is to optimize noncommodity attributes of uneven-aged stands (as it may be for certain private landowners, public agencies, and conservation organizations), then it may prove more beneficial to identify large, low-productivity pines to ensure that at least some of these are retained. For instance, the pines with red-heart fungus (*Phellinus pini* Thore:Fr.) needed to facilitate cavity excavation by the federally listed red-cockaded woodpecker (*Picoides borealis* Vieillot) are large, old, slow-growing trees (Conner and O'Halloran 1987, Masters et al. 1989, Conner et al. 1994). Given our experience on the Farm Forties, it is possible in uneven-aged stands to accumulate such specimens that can meet the age thresholds (between 70 and 80 years for loblolly; Jackson et al. [1979]) for extensive red-heart formation without dramatic decreases in timber production. Data from this study (Figures 4 and 5) clearly show a substantial proportion of the larger overstory pines older than 70 years in both the Farm Forties even without specific management for this attribute. The implications for stand development, regulation, and growth and yield by systematically retaining numbers of these trees per acre indefinitely, however, have yet to be fully explored.

Conclusions

The Good and Poor Farm Forestry Forties on the CEF are the oldest and best-documented examples of sustainable, multiaged stands in the southern United States (Guldin 2011). More than seven decades of management on the CEF using regulation methods intended to maintain multiple age cohorts demonstrate the robustness of this silvicultural system in loblolly and shortleaf pine-dominated forests on these coastal plain sites. The selection method practiced by Reynolds has proved to be an effective tool to restore cutover stands to full stocking and to improve the quality of forest products over time (Reynolds 1959, Reynolds et al. 1984, Baker 1986, Guldin 2011).

Our sample of loblolly and shortleaf pines yielded a wide range of age classes with few discrete or discernible age cohorts, a product of annual harvests during the first decades of these demonstration areas, followed by more prolonged recruitment in later years as site modification due to periodic harvesting and competition control efforts increased. Among the more notable findings of this study is that more than 90% of the trees currently in the Farm Forties, some of which had grown into the 26- to 27-in. dbh class cut in 2011, germinated after the study was established in 1937. Roughly 20% of the pines in these stands are >18 in. in dbh and thus are eligible for harvest at any time. The smallest size classes are also well represented across both compartments. These attributes speak to the long-term sustainability of uneven-aged silviculture in these intolerant southern pine stands.

Finally, the rate of development of trees from seedlings to harvest in these uneven-aged stands in southern pines is noteworthy. Few other managed uneven-aged forests in the world grow in basal area and volume as rapidly and can be managed using cutting cycles as short as those for these southern pine stands (Guldin 2011). Furthermore, the presence of some old pines of size (diameter) similar to that of much younger canopy dominants suggests that a number of silvicultural options are possible, spanning the range from intensified timber production to greater opportunities for certain wildlife species dependent on old trees. Unfortunately, we lack the information necessary to determine whether either of these management extremes can be optimized by modifying the stocking and stem location patterns or whether both could coexist under some kind of a novel arrangement. Although it would take decades to quantify this situation in the field, it may be possible to simulate these conditions in a model capable of expressing the growth, spacing, and age structure of uneven-aged southern pine stands.

Endnotes

1. Hereafter, the CEF's Good Farm Forestry Forty will be called the "Good Forty," the Poor Farm Forestry Forty will be called the "Poor Forty," and collectively they will be referred to as the "Farm Forties."
2. All board foot (bd ft) volumes in this paper use the Doyle log rule, with a minimum tree dbh of 11.6 in.

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