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Experience with the selection method in pine stands in the southern United States, with implications for future application

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Summary

The selection method applied in shade-intolerant pine stands in the southern United States has been shown to be an effective method of uneven-aged silviculture, but it is becoming less frequently practiced for a variety of reasons. Economically, the high value of standing timber puts fully stocked uneven-aged pine stands at risk of liquidation if the timberland is sold. This is increasingly common on private lands in the southern United States, where forest industry landowners have been selling timberlands over the past two decades to timber investment management organizations and real estate investment trusts. Ecologically, the benefits of open woodland habitat restoration in southern pines are being optimized by use of prescribed burning, which is much more adaptable to even-aged silvicultural systems such as the shelterwood method than it is to the selection method. But uneven-aged silviculture will be important in the twenty-first century; its values centre around the ability of uneven-aged stands to resist and especially to recover from exogenous disturbance events, as well as the opportunity for frequent establishment of new regeneration cohorts under changing climatic conditions.

Introduction

The pine-dominated forests in the upper West Gulf Coastal Plain region of southern Arkansas, northern Louisiana, eastern Oklahoma and eastern Texas in the south-central United States are among the most productive timberlands in the nation. Native pine forests in this region are found on upland sites and are dominated by mixed stands of loblolly pine (*Pinus taeda* L.) and shortleaf pine (Pinus *echinata* Mill.). Prior to 1900, these stands consisted of open woodlands with relatively low basal area, and standing volume was concentrated in a few large trees per hectare (Bragg, 2002). That large-tree character led to the harvest of virgin stands by selective cutting of pines larger than 38 cm in diameter at the stump or roughly a 30-cm diameter at breast height (d.b.h.) limit (Guldin, 2002). But in the first half of the twentieth century, the mills that cut the virgin stands adapted to manage the pine stands that remained after high grading, coincident with the rise of the forestry profession in North America (Dana, 1951). Today, the region supports a strong forest industry based on managing these timberlands using both even-aged and uneven-aged silvicultural systems (Guldin, 2004).

The region's climate is mild; mean monthly temperatures that vary from 7°C in January to 28°C in July (Reynolds, 1959). Precipitation averages 140 cm annually based on local records, but growing season droughts of from 20 days to 2 months are not uncommon (Stahle *et al.*, 1985). Geologically, the region is composed of marine terrace deposits from the Cretaceous and early Tertiary periods (Bragg, 2002). Topography in the region is gentle, slopes are typically less than 5 per cent, and elevation averages 50 m above mean sea level. Soils tend to be deep and medium textured, somewhat poorly drained, with relatively low nutrients and organic content (Walker and Oswald, 2000). Surface soils are light coloured and tend to be sandy in texture with a varying layer of loessial deposition from 10 to 15 cm in thickness; subsoils contain more clay and tend to be red, yellow, grey and somewhat mottled (Reynolds, 1959). Sites are productive, supporting average site index of 30 m at 50 years (Farrar *et al.*, 1984). Major natural disturbance events affecting the region include fire, windthrow, ice storms, drought, lightning and insect outbreaks (Bragg, 2002). Fire, whether natural or human caused, is thought to have had a strong influence in maintaining pine-dominated forests in the region (Chapman, 1942).

Much of what is known about uneven-aged silviculture in the region developed through research by Chapman (1942) on lands of the Crossett Lumber Company and subsequently from studies at the Crossett Experimental Forest, established in 1934 by the US Forest Service and located 20 km south of the mill town of Crossett in Ashley County, AR (Reynolds, 1980). Widespread cutting of the virgin mixed loblolly and shortleaf pine forests from to 1930 resulted in stands that were considerably understocked and unproductive (Reynolds, 1947, 1959). Early research demonstrated that the selection method is a cost-effective way to quickly restore the productivity and stocking of understocked stands (Reynolds, 1959, 1969), and the method was widely applied to bring millions of acres of cutover understocked southern pine timberlands back to fully stocked conditions in the 1950s and 1960s (Reynolds, 1980; Baker, 1986). But the inherent productivity of these timberlands has resulted in dramatic changes across the landscape over the past 50 years. Between 1960 and 2010, and especially in the last two decades, fully-stocked even-aged and uneven-aged pine stands on forest industry land have been converted to short-rotation even-aged pine stands established using the clearcutting method (Gladstone and Ledig, 1990; Allen *et al.* 2005). The even-aged pine plantations established after clearcutting are managed for optimum growth to produce small sawlogs from 30 to 40 cm in d.b.h. using rotations ages from 20 to 30 years (Allen *et al.*, 2005; Fox *et al.*, 2007).

This shift raises questions about whether uneven-aged silviculture has a role in forest management in southern pines in the future. The advantages and disadvantages of the selection method in the loblolly–shortleaf pine forest type have been well documented (Williston, 1978; Gibbs, 1978; Baker and Murphy, 1982; Baker *et al.*, 1996; Guldin, 1996; Guldin and Baker, 1998). It is an excellent tool to restore stands that have been cutover and are in understocked condition, such as recently cutover naturally regenerated stands (Baker and Shelton, 1998a), naturally regenerated unmanaged understocked stands cut 15 years previously (Baker and Shelton, 1998c), and understocked seedling–sapling stands of naturally regenerated or planted origin (Baker and Shelton, 1998d). This recovery is largely a function of the silvics of loblolly and shortleaf pine that enable individual trees to respond to release at advanced age, provided that the tree supports a live crown ratio greater than 20 per cent and a stem diameter at the base of the live crown greater than 5 cm (Baker and Shelton, 1998b). These pines produce adequate or better seed crops 75 per cent of the time (Cain and Shelton, 2001b), and that influx of natural regeneration allows new age cohorts to be established at a fraction of the cost of even-aged plantations. Growth rates are rapid, which enables short cutting cycles on the order of 5–7 years, and these frequent harvests provide a periodic income composed primarily of high-quality sawtimber for the landowner (Farrar *et al.*, 1984; Baker, 1986; Guldin and Baker, 1988; Guldin and Fitzpatrick, 1991; Guldin and Baker, 1998; Guldin, 2002).

On the other hand, the selection method is not as efficient in production of pulpwood and fibre (Williston, 1978; Guldin and Baker, 1988; Cain and Shelton 2001a), especially compared with pine plantations in the region. Regulation of harvest and control of stocking is technically demanding in uneven-aged stands (O'Hara and Gersonde, 2004), compared with even-aged stands managed using area-based regulation methods (Williston, 1978). In terms of present net value, the standing volume of uneven-aged stands represents a capital asset that must be capitalized, which dramatically reduces present net value of uneven-aged stands especially when interest rates are high (Hotvedt *et al.*, 1989; Hotvedt and Ward, 1990). Optimum levels of growing stock are difficult to determine, especially under varying cutting cycles and changing market conditions (Chang and Gadow, 2010), and some models suggest optimal levels of basal area and maximum retained diameter (Schulte and Buongiorno, 1998) that are lower than observed in an operational context and arguably unsustainable from a silvicultural context. Finally, an important ecological concern is the difficulty of using prescribed burning in uneven-aged stands (Williston, 1978); prescribed burns conducted on a 3-year cycle do not allow natural pine regeneration to reach a size that can escape the subsequent fire (Cain, 1993; Cain *et al.*, 1998; Shelton and Cain, 2000; Cain and Shelton, 2002).

Long-term observations in pine stands managed using the selection method

The longest continuously managed uneven-aged southern pine stands in the southern US are the Good Forty (Figure 1) and the Poor Forty (Figure 2) Farm Forestry Demonstration Areas at the Crossett EF in southeastern Arkansas. These unreplicated stands were established in 1937 and have since been continuously managed using uneven-aged silviculture under the volume control-guiding diameter limit regulation method (Reynolds *et al.*, 1984; Guldin and Baker 1998; Guldin, 2002). A recent study to quantify tree age in these two stands found that only 5 per cent of the trees measured for age were older than 73 years old, and thus, most of the trees up to 75 cm in d.b.h. in these stands germinated as seedlings after the demonstration was initiated in 1937 (Bragg, D.C., in press). There are probably no other uneven-aged stands in the world where such a large percentage of stems have germinated after the establishment of the demonstration.

The difference in the 'Good' and 'Poor' Forty stands in 1937 was not related to site quality. Both stands are on similar sites that are highly productive. Rather, the difference in 1937 was the initial stocking in the two stands; the Good Forty was fully stocked, but the Poor Forty was less than 50 per cent stocked (Reynolds, 1959; Guldin, 2002).

Figure 1. Typical stand structure in the Good Forty demonstration stand at the Crossett EF, Ashley County, AR. (Photo by James M. Guldin, May 2006.)

A key early finding in the study was that by 1951, after 15 years of annual harvests, the Poor Forty had recovered to full stocking (Reynolds, 1959). Since that time, annual sawlog volume growth on both Forties has been more or less equivalent (Reynolds, 1959, 1969; Reynolds *et al.*, 1984). Annual harvests continued until 1968, and since then the stands have been cut seven times with the last cutting cycle harvest in 2002. Since 1951, both stands have remained similarly productive and fully stocked (Table 1). In 2005, the standing sawtimber volume on the Good Forty and Poor Forty had a stumpage value of €4134 and €4115 ha^{-1}, respectively, based on recent stumpage values in the region and a conversion of 1.30 dollars $Euro^{-1}$.

The objective of management in the Good and Poor Forty stands over the years has been to produce high-quality construction lumber milled from trees 50 cm d.b.h. and larger (Reynolds, 1959, 1969; Reynolds *et al.*, 1984; Guldin and Baker, 1998; Guldin, 2002). For example, over the past 30 years, the Poor Forty has had four cutting cycle harvests, and the Good Forty has had the same plus a salvage cut from a disturbance in 1983 (Table 2). The total merchantable volume (trees > 10 cm d.b.h.) harvested was 5.53 and 5.18 m^3 ha^{-1} $year^{-1}$, and the sawlog volume (trees > 30 cm d.b.h.) was 4.72 and 4.55 m^3 ha^{-1} $year^{-1}$, in the Poor Forty and Good Forty, respectively. On average, the value from harvests over that period of time was roughly €200 ha^{-1} $year^{-1}$. This shows the sustainability of volume and value over the past 30 years and is more or less consistent with sustained volume production over the 69 years of management of these demonstrations.

Constraints in the selection method

Yet, despite this demonstrated record of sustained volume growth and periodic financial returns of value to the landowner, uneven-aged silviculture is becoming less frequently practiced in the southern United States, down from an estimated 1.3 million ha in 1960 to less than 80 000 ha in 2010 (E. Lovett, Larson and McGowin, Inc., Mobile, AL, personal communication). This is so for a variety of economic and ecological reasons, and the decline in practice raises questions about whether the method is a viable silvicultural alternative in the twenty-first century.

Economics

Ironically, fully stocked uneven-aged pine stands in the southern US are to a certain extent a victim of their own success. The high stumpage value of standing timber puts uneven-aged stands at risk of liquidation when the ownership of forest stands changes hands. This is increasingly common on private lands in the southern US, where industry-owned forest lands are being sold for timber investments or real estate trusts (Binkley *et al.*, 1996; Bliss *et al.*, 2010). The new forest landowner is under no obligation to continue the silvicultural systems being practiced on the lands they have acquired. As a result, the sale presents the new owners with a decision. Should they continue to manage any uneven-aged stands they acquire using the selection method, or should they clearcut those stands and establish modern plantations using genetically improved pine planting stock? Data from the Farm Forestry Forties at Crossett suggests that the value of continued cutting-cycle harvests is on the order of €1000 ha^{-1} every 5 years, whereas the liquidation value of the timber in a well-stocked uneven-aged stand is €4,000 ha^{-1} in the short term. Presented with economic planning horizons driven by short-term investment portfolio analysis, many of these new landowners have decided to 'go for the gold', so to speak. They make a short-term investment decision to clearcut the stand, which then leads to intensive site preparation and planting (which together cost more than €1000 ha^{-1}) and a *de facto* decision to manage for short-rotation pulpwood and small sawtimber products. The wisdom of this short-term decision on long-term forest value is cloudy.

Ecological restoration

In the mixed loblolly–shortleaf pine stands in the region, ecological restoration refers to management practices intended to approximate old-growth conditions (Bragg,

Figure 2. Typical stand structure in the Poor Forty demonstration stand at the Crossett EF, Ashley County, AR (Photo by James M. Guldin, May 2006.)

Table 1: Standing inventory in 1936 and 2005, and annual growth and cut over 69 years under the selection method, for the Good and Poor Forty stands at the Crossett EF, Ashley County, AR

	Stem density		Basal area		Volume	
Year	>10 cm (trees ha^{-1})	>30 cm (trees ha^{-1})	>10 cm (m^2 ha^{-1})	>30 cm (m^2 ha^{-1})	>10 cm (m^3 ha^{-1})	>30 cm (m^3 ha^{-1})
Poor Forty						
1936	210.0	42.0	8.7	4.8	68.29	36.11
2005	190.2	74.1	13.5	11.2	121.68	91.45
Good Forty						
1936	326.0	74.1	15.4	9.2	125.39	71.44
2005	180.3	71.6	13.3	11.2	119.72	91.87
Poor Forty						
Cut per year	9.4	3.5	0.69	0.55	6.36	4.62
Growth per year	–	–	0.76	0.64	7.14	5.46
Good Forty						
Cut per year	7.2	2.7	0.586	0.482	5.55	4.31
Growth per year	–	–	0.556	0.519	5.46	4.62

2002) characterized by mature stands of large pines with an open understory maintained by the use of fire. The history of fire ignition in the eastern US is a history of anthropogenic ignitions (Guyette and Spetich, 2003), including the period that predates European colonization. It is difficult to quantify the historical frequency and extent of fire occurrence in the region, but descriptions of forest structure from written accounts suggest that open woodlands were common and that fire promoted those conditions (Bragg, 2002).

Fires continued to occur during the early stages of European colonization and through the cutting of the virgin forest; Olmsted (1902) noted that only 5 per cent of the surveyed forest lands had escaped serious fire in the preceding decade and that on badly burned areas all young growth less than 6 m in height was completely destroyed. The dangers of uncontrolled forest fires in the colonized South became so apparent that from the 1930s onward, controlling wildfire became an essential first step in

Table 2: Thirty years of harvest activity from 1979 to 2009 on the Good and Poor Forty stands at the Crossett EF, Ashley County, AR

	Stems harvested			Volume harvested		
	Trees (trees ha^{-1})	Basal area (m^2 ha^{-1})	Mean d.b.h. (cm)	Trees > 10 cm (m^3 ha^{-1})	Trees > 30 cm (m^3 ha^{-1})	Stumpage (Euro ha^{-1})
Poor Forty						
November 1979	Last cut					
November 1985	35.1	5.1	43.2	49.24	41.44	€1744.49
December 1990	43.7	5.2	38.9	48.27	39.24	€1551.16
July 1997	18.7	3.4	47.9	32.86	28.73	€1316.75
November 2002	16.0	3.6	53.6	35.54	32.11	€1560.68
30-Year sum	113.4	17.3	–	165.91	141.52	€6173.08
Annual	3.8	0.6	44.1	5.53	4.72	€205.77
Good Forty						
September 1979	Last cut					
July 83	12.8	2.2	47.2	21.64	19.37	€949.39
November 1985	22.3	3.6	45.4	34.80	30.32	€1424.52
December 1990	40.4	5.3	41.0	50.28	41.98	€1782.91
July 1997	8.8	1.8	51.7	18.00	16.25	€790.37
November 2002	12.1	3.1	57.2	30.79	28.62	€1465.25
30-Year sum	96.5	16.1	–	155.52	136.54	€6412.44
Annual	3.2	0.5	46.2	5.18	4.55	€213.75

restocking pines in cutover forests of the region (Reynolds *et al.*, 1944). State and Federal agencies worked hard to control wildfire, even to the extent of dismissing controlled burning as a legitimate silvicultural tool (Chapman, 1947), especially in developing uneven-aged pine stands (Bull *et al.*, 1943). This historic pattern of management across the landscape of the region—harvest of the virgin forest, aggressive efforts at reforestation, and control of wildfires—has led to a reduction in area of mature open woodlands and the concomitant decline of many species of flora and fauna that depend upon those open conditions (Bragg, 2002).

As a result, management of Federal, State and some private pine-dominated timberlands across the southern US at the start of the twenty-first century has emphasized restoration of open woodland habitat. The tools most commonly used for this are even-aged silvicultural systems such as the shelterwood method, thinning to remove the midstory, and re-introduction of periodic prescribed burning (Rudolph and Conner, 1996; Hedrick *et al.*, 1998). This approach has been successful in restoring the desired open habitat (Figure 3) and demonstrates the value of even-aged silvicultural systems in a 'back-to-nature' approach to forest management. But because of the difficulty in integrating prescribed burning with establishment and development of pine seedlings and saplings (Cain, 1993; Cain *et al.*, 1998; Shelton and Cain, 2000; Cain and Shelton, 2002), uneven-aged silviculture is not very popular in the southern US when the goal is to restore open pine woodlands.

Opportunities for future application of the selection method

In the face of changing land ownership, popularity of clearcutting on industry and investment timberlands, and restoration prescriptions that rely on the even-aged shelterwood method, the future of uneven-aged silvicultural systems for pine-dominated stands in the southern US might seem bleak. But the future of the region includes the likelihood of changing climatic conditions (Dale *et al.*, 2001; Malmsheimer *et al.*, 2008). Limiting the global effects of climate change is outside the definition of silviculture; climate change is an issue at much, much larger geographic scales. However, the interplay of climate change at the scale of the forest stand and landscape is something that a silviculturist can address, and uneven-aged silviculture may have value in pine-dominated forest types in this context. These values centre around two important attributes—the ability of the selection method to rehabilitate understocked stands, and the genetic variability resulting from frequent periodic establishment of new regeneration cohorts.

Climate change is likely to result in changing patterns of stand-level disturbance; the frequency, severity and duration of disturbance events are likely to be different than that which was observed in the past (Dale *et al.*, 2001). The silviculturist can work with this knowledge to promote stand structural conditions that are resistant or resilient to enhanced disturbance effects. Data from research studies at the Crossett EF show that mature loblolly–shortleaf pine stands that are suddenly understocked to levels as low as 30 per cent of full stocking can recover to fully stocked sawtimber stands within 15 years, at an out-of-pocket cost much less than that incurred by clearcutting the remains of the understocked stand and planting a new stand (Baker and Shelton, 1998a, 1998b, 1998c, 1998d).

This has important implications for pine stands affected by exogenous disturbance events. For example, in widespread wind disturbances such as hurricanes, this research can give silviculturists a 'triage' tool to apply to an affected landscape. The stands in the affected area that have 30 per cent

Figure 3. Pine woodland habitat restoration in a shortleaf pine stand in the Ouachita Mountains, Scott County, AR (Photo by James M. Guldin, January 2010.)

stocking or better can be managed under the selection system and restored to full stocking in 15 years; the stands that have stocking levels below 30 per cent can be liquidated and managed using even-aged plantation methods. This is significant because a stand at 30 per cent stocking looks devastated to the forester at first glance, and the forester might thus prescribe costly clearcutting and planting in more stands than might be needed. This concept of understocked stand rehabilitation can probably be adapted to other forest types on other continents especially those where experience with uneven-aged silviculture is found, though the specific stocking level in a different forest type might vary.

Secondly, as climate changes in the region, one can speculate that the pines that will grow into the dominant canopy will be those that were successful competitors in the environment in which they became established and subsequently developed. If the future patterns of weather and climate at a given location are uncertain, it will be important for any new naturally regenerated age cohorts to be genetically diverse. This will increase the likelihood that some individuals will be more adapted to the changing environment than others, will be able to outcompete their neighbours and in the end will be more likely to survive to maturity.

One might further speculate that if changing climatic conditions occur rapidly, the rate of establishment of new age cohorts becomes important so that stands will contain trees adapted to the changing local conditions. This is an advantage because uneven-aged stands contain more age cohorts established more frequently than even-aged stands. For example, in the southern US, even-aged pine stands managed using the shelterwood method on industry timberlands have rotation ages of 40–50 years (Zeide and Sharer, 2000); pine plantations on industry timberlands are managed to rotation ages of 20–30 years (Gladstone and Ledig, 1990; Allen *et al.* 2005; Fox et al., 2007). Conversely, well-managed uneven-aged pine stands such as the Good and Poor Forty stands in Arkansas produce a new age cohort during every cutting cycle harvest or 2 or every 5–10 years (Guldin, 2002). If climate is changing at a rate that affects forest stand development, there may be an advantage in obtaining a new age cohort every decade rather than every 20–50 years. Given the uncertainty of exact predictions about the potential scale and scope of climate change, a proactive approach that ensures genetic diversity of new age cohorts obtained every decade or two over time may become important, a attribute to which uneven-aged stands are ideally suited.

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