THE PLANTATION CONVERSION DEMONSTRATION AT THE CROSSETT EXPERIMENTAL FOREST—IMPLICATIONS FOR CONVERTING STANDS FROM EVEN-AGED TO UNEVEN-AGED STRUCTURE

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Abstract—In the absence of replicated studies, we used a case study demonstration to illustrate converting a 26-year-old even-aged loblolly pine (*Pinus taeda* L.) plantation to uneven-aged structure. Unreplicated treatments included maintaining even-aged structure through low thinning (thinning from below) to a residual basal area of 80 square feet per acre, and two methods of converting to uneven-aged structure-one using the volume control guiding diameter limit method, and the other using the BDq method of structural regulation. Over 12 years, all three treatments had a periodic annual increment of over 90 square feet per acre in both total merchantable and sawtimber cubic volume; all three treatments also maintained annual sawtimber volume growth rates of 90-100 square feet per acre, 450-600 board feet per acre Doyle rule, and 600-750 board feet per acre International ¼-inch rule. In all volume increment measurements, the even-aged treatment exceeded the volume control method, which exceeded the BDq method. Conversely, the BDq method was the only treatment in which adequate pine regeneration was established and making acceptable development; regeneration development in the volume control treatment was marginal, and it was unacceptable in the even-aged treatment. After 12 years, residual basal area levels exceeded 60, 75, and 100 square feet per acre in the BDq, volume control, and even-aged treatments, respectively. To increase the reliable development of regeneration in these treatments, lower residual basal areas should be considered.

INTRODUCTION

Over the past two decades, interest has grown in converting even-aged stands to uneven-aged structure. A public forest land manager or a private forest landowner might consider this conversion because uneven-aged stands have more heterogeneous within-stand habitat and structural attributes than plantations. Examples include enhanced vegetation or wildlife species diversity, or a more gradual flow of higher-value products than plantations typically provide.

Conversion of uneven-aged to even-aged conditions can be accomplished very quickly—either by clearcutting and planting, or by harvesting to a seed-tree or shelterwood residual basal area (RBA) and encouraging the development of natural regeneration from seed that fall from the residual stand. Conversion from even-aged to uneven-aged conditions takes more time, because trees in the submerchantable size classes are usually not present in sufficient numbers. Development of an uneven-aged diameter distribution may take several cutting cycles, during which time it will be desirable also to maintain adequate volume production.

However, scientific evidence supporting conversion of even-aged to uneven-aged stands, especially in plantations, is limited. Most studies and demonstrations of uneven-aged silviculture in southern pines have focused on recovery from understocked conditions rather than conversion of fully-stocked even-aged structure; this is the case for the Good Farm Forestry Forty and especially the Poor Farm Forestry Forty at the Crossett Experimental Forest in southern Arkansas (Reynolds and others 1984), the Hope Farm Forestry Demonstration at Hope, AR (Farrar and others 1984a), and the Mississippi State Farm Forestry Forties on the Starr Memorial Forest near Starkville, MS (Farrar and others 1989).

The best example of converting even-aged plantations to uneven-aged structure is the Dauerwald, established in the late 19th and early 20th century in southeastern Germany in the state of Anhalt. Stands managed using the Dauerwald were Scotch pine (*Pinus sylvestris* L.) plantations on relatively poor sites with sandy soils, limited vegetative competition, and abundant naturally-occurring regeneration. Those conditions promoted the establishment and development success of regeneration in the smaller size classes, and over time that led to the success of the new method (Troup 1928, Troup 1952).

However, no current replicated research studies to convert even-aged plantations to uneven-aged structure are available for any of the major southern pines in the southern U.S. Therefore, non-replicated demonstrations are an alternative source of data on the mechanics of plantation conversions. One such study is underway in the upper West Gulf Coastal Plain for loblolly (*P. taeda* L.) pine

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plantations is the Plantation Conversion Demonstration at the Crossett Experimental Forest.

Our objectives have been to investigate the conversion of even-aged plantations to uneven-aged structure. In the demonstration, two methods of regulating uneven-stands and one method of maintaining even-aged conditions are compared.

METHODS

The demonstration was established in 1980 by the junior author in a 26-year-old loblolly pine plantation located in Compartment 61 of the Crossett Experimental Forest, located in Ashley County approximately 7 miles south of Crossett, AR. Site index for loblolly pine in the study area is 95 feet (base age 50 years). Soils are of the Providence and Bude series, loamy to silt loam in texture, and are poorly drained to moderately well drained.

Three plots, each approximately four acres in size, were located within the plantation. One of three treatments was applied randomly to each plot:

1) Even-aged 80 RBA—-Thinned periodically from below, if operable, to leave 80 square feet per acre of residual basal area.
2) Uneven-aged volume control-guiding diameter limit method (VCGDL)-—Using the volume control-guiding diameter limit method of regulating uneven-aged stands developed by Reynolds (Reynolds and others 1984), stands were operationally treated through periodic cutting until before-cut stand volumes sup ported about 75 square feet per acre of basal area, 2000 cubic feet per acre of total merchantable cubic volume, and 7000 board feet Doyle per acre.
3) Uneven-aged BDq method (BDq)—-The stand was regulated through cutting-cycle harvests using a BDq target stand as the marking guide, where the target stand is set at a residual basal area (the “B” in the BDq acronym) of 60 square feet per acre, a maximum retained d.b.h. (D) of 22”, and a q (1-inch classes) of 1.2 (Baker and others 1996).

All three plots were burned by prescription for brush control and hazard reduction during the 1979-80 dormant season prior to study installation. Since then the 80 RBA treatment was burned by prescription during dormant seasons of 1983-84, 1986-87, and 1989-90. All three plots also were treated with herbicides to control unwanted hardwood vegetation; this treatment consisted of basal stem injection of hardwoods 1” d.b.h. and larger using Tordon 101R (picloram plus 2,4-D) in March 1981. In September 1991, a second hardwood control treatment was applied to the uneven-aged plots, consisting of 16 oz. of Arsenal AC (imazapyr) applied using a broadcast sprayer mounted on an articulated rubber-tired skidder.

Data were reported for 12 growing seasons—-summer 1980 through summer 1991. Harvest activity, and inventories to quantify harvest, were conducted during February-March 1981 as the demo was installed, and during the winters of 1983-84 when all plots were harvested, 1986-87 when only the uneven-aged plots were harvested, and 1991-92 when harvest activity occurred on all plots. Inventories of overstory trees were based on 100-percent tallies of all trees 3.6 inches d.b.h. and larger, which were recorded by 1-inch diameter classes and as either pine or hardwood. Overstory plot cruises were conducted, and stands were marked and cut, in each of the dormant seasons of 1980-81, 1983-84, 1986-87, and 1991-92. Marking tallies were also 100-percent tallies of marked trees, recorded by 1-inch d.b.h. classes. After-cut stand conditions were determined by subtracting the marking tally from the cruise tally. For all plots, stand tables were prepared from cruise data using local volume tables.

Regeneration data were tallied as pine or hardwood by 1-inch d.b.h. classes from 0 inches to 3 inches, based on the following classification:

1) 0-inch class—all trees greater than 6 inches in height up to 4.5 feet in height, and if greater than 4.5 feet in height, = 0.5 inches d.b.h.
2) 1-inch class—trees 0.6 inches = d.b.h. = 1.5 inches
3) 2-inch class—trees 1.6 inches = d.b.h. = 2.5 inches
4) 3-inch class—trees 2.6 inches = d.b.h. = 3.5 inches

In the 1980-81 and 1983-84 measurements, regeneration was tallied on 50 0.01-acre fixed-radius plots, by species and diameter class. In the 1986-87 and the 1991-92 measurements, 100 0.001-acre fixed-radius plots (milacres) were sampled for the 0-inch class; for these, milacre stocking percentages were calculated by treatment. In addition, 50 0.01-acre fixed-radius plots were sampled for the 1-inch, 2-inch, and 3-inch classes.

Because overstory data were based on 100-percent tallies, and regeneration data were not replicated, statistical comparisons were not used. Instead, data were presented as summaries for the respective treatments.

RESULTS

Stand Structure over Time

The 80 RBA showed a textbook progression of stand development over time in response to thinning (figure 1). Low thinning removed largely the suppressed,

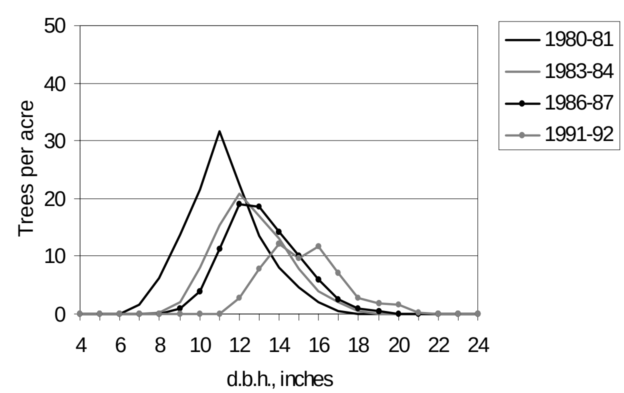

Figure 1—Diameter distribution of the pine component in the even-aged 80 RBA treatment during 1980-81, 1983-84, 1986-87, and 1991-92.

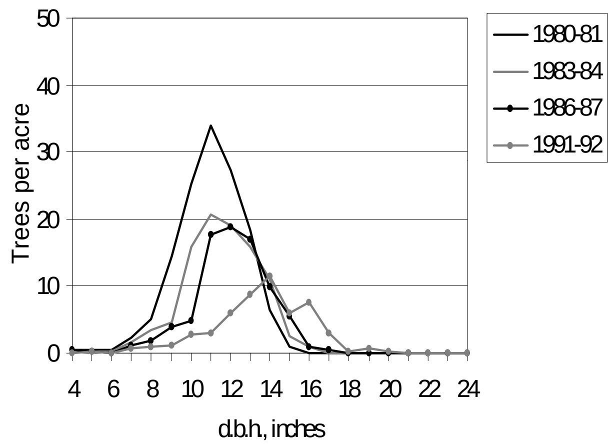

Figure 2—Diameter distribution of the pine component in the uneven-aged volume control-guiding diameter limit treatment during 1980-81, 1983-84, 1986-87, and 1991-92.

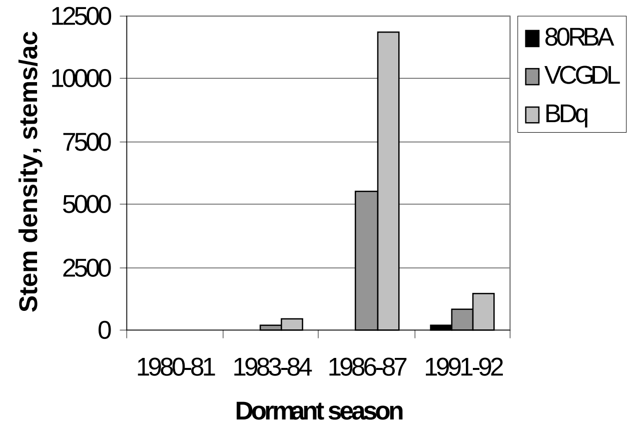

Figure 4—Pine regeneration density by treatment, 0-inch to 3-inch classes inclusive, during 1980-81, 1983-84, 1986-87, and 1991-92.

intermediate, and poorer codominant trees during each harvest. This drove the observed increase both in median diameter and in the size of the smallest trees that remain.

The VCGDL treatment showed a different pattern of residual stands over time (figure 2). Regulation in the VCGDL was done in the sawtimber classes, and the key to implementing the VCGDL method was to “cut the worst trees and leave the best” throughout the range of sawtimber diameters. As a result, there was more whittling away in the larger sawtimber diameter classes than in the low thinning of the 80 RBA treatment and less dramatic shifts in the median diameter. Also, in the VCGDL method, pulpwood-sized trees often were allowed to persist in the stand until they crossed the sawtimber size threshold; a tree’s value in board feet is 4 to 10 times greater than its corresponding pulpwood-based cubic-foot value. This resulted in less incentive to remove trees in the subsawtimber classes.

The same principle of ‘cut the worst and leave the best’ applied in the BDq method (figure 3). But where the VCGDL method encourages the forester to cut the worst and leave the best across all sawtimber diameter classes, the BDq method guides the forester to apply this principle within each merchantable diameter class. This leads to the more obvious pattern of ‘taking the top’ off the normal curve in the sawtimber component, and shaping the diameter distribution to conform more closely and more rapidly to the reverse J-shaped BDq target distribution.

Periodic Annual Volume Increment

The 12-year periodic annual increment (PAI) for all three treatments exceeds 80 cubic feet per acre for total merchantable cubic volume, and 90 cubic feet per acre for sawtimber cubic volume (table 1). The 80 RBA treatment had the highest values for these variables, exceeding 100 cubic feet per acre annually for the 12-year period. The uneven-aged VCGDL treatment also exceeded 100 cubic feet per acre annually. The BDq treatment had the lowest PAI, falling roughly 20 percent behind the 80 RBA treatment in total merchantable cubic volume, and 13 percent less than the 80 RBA treatment in sawtimber cubic volume.

Twelve-year PAI trends for the sawtimber board foot measures were similar (table 1). All treatments exceeded

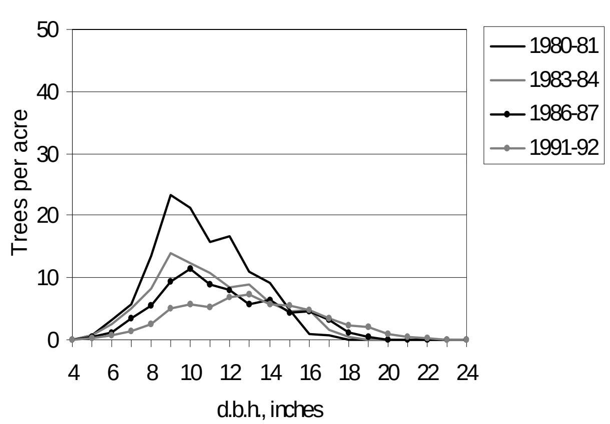

Figure 3—Diameter distribution of the pine component in the uneven-aged BDq treatment during 1980-81, 1983-84, 1986-87, and 1991-92.

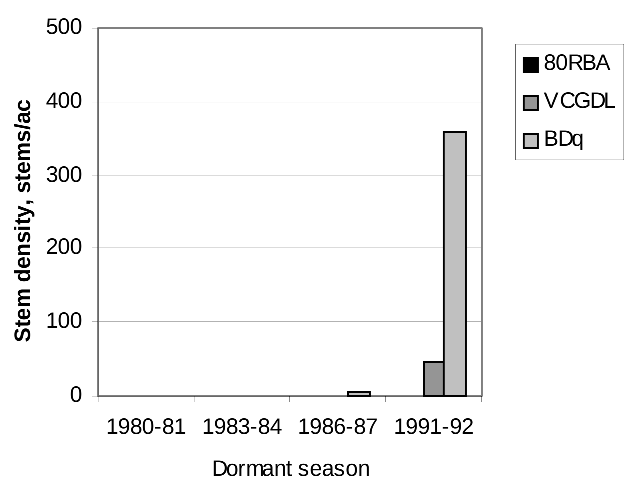

Figure 5—Pine regeneration density by treatment, 1-inch to 3-inch classes inclusive, during 1980-81, 1983-84, 1986-87, and 1991-92.

Table 1—Periodic annual volume increment over 12 growing seasons for the three treatments. TMCV, total merchantable cubic volume; SCV, sawtimber cubic volume, Doyle, sawtimber board-foot volume under the Doyle log rule; Intl. ¼, sawtimber board-foot volume under the International ¼-inch log rule

	TMCV ft^3/ac	SCV ft^3/ac	Doyle fbm/ac	Intl. ¼ fbm/ac
80RBA	106.3	108.0	566.8	716.9
VCGDL	99.7	103.0	493.7	675.3
BDq	84.9	93.6	465.5	633.0

Table 2—Percentage of after-cut basal area in trees 11.6 inches d.b.h. and larger, by inventory year and treatment

	1980-81 *percent*	1983-84 *percent*	1986-87 *percent*	1991-92 *percent*
80RBA	53.8	80.8	88.2	100.0
VCGDL	50.7	63.7	74.4	91.1
BDq	51.4	60.0	66.2	79.0

450 board feet per acre Doyle, and 600 board feet per acre International ¼-inch rule, annually. Again, the 80 RBA treatment was best, the VCGDL treatment was intermediate, and the BDq treatment was poorest. The BDq method had roughly 18 percent less Doyle board foot volume, and 12 percent less International ¼-inch volume, than the 80 RBA treatment. However, the 12-year PAI for all three treatments exceeds the 37-year average annual production of the Good and Poor Farm Forestry Forties for these three volume variables (Guldin and Baker 1988).

Pine Regeneration Density

The cyclical nature of pine regeneration in uneven-aged stands was readily apparent when all regeneration classes were considered (figure 4). By the 1986-87 growing season, pine regeneration density exceeded 5,000 stems per acre in both uneven-aged treatments. But over the next 6 years, those numbers dropped to slightly more than 500 stems per acre of pine regeneration. Pine regeneration did not become established in the even-aged RBA 80 treatment, and none was expected; the 3-year cyclic prescribed burn treatment destroyed most of the pine regeneration that had become established.

Examination of the 1-inch to 3-inch size classes gave a better impression of the successful development of regeneration into larger regeneration classes (figure 5). Provisional standards for acceptable regeneration (Baker and others 1996) suggest that uneven-aged stands require a minimum of 200 stems per acre of desired reproduction. By this standard, only the BDq treatment was effective in promoting development of regeneration into stems larger than 0.5 inch in diameter after 12 years.

Milacre stocking data also show the decline in numbers from 1986-87 to 1991-92 (figure 6). According to Baker and others (1996), the standard for minimum acceptable milacre stocking of desired species is 20 percent. By that standard, both uneven-aged treatments had acceptable milacre stocking in 1986-87, because the VCGDL

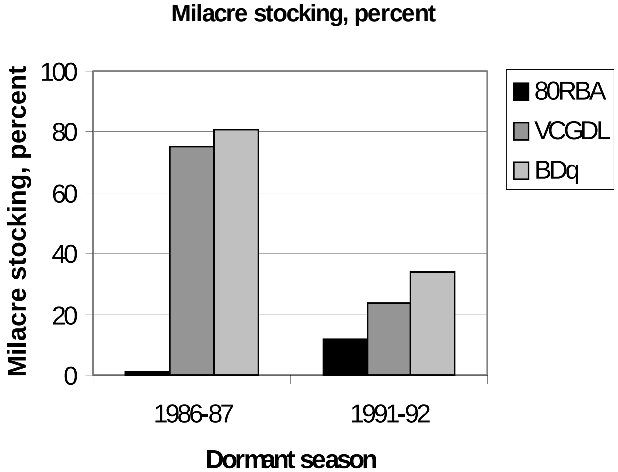

Figure 6—Milacre stocking of pine regeneration by treatment, 0-inch to 3-inch classes inclusive, during 1986-87 and 1991-92.

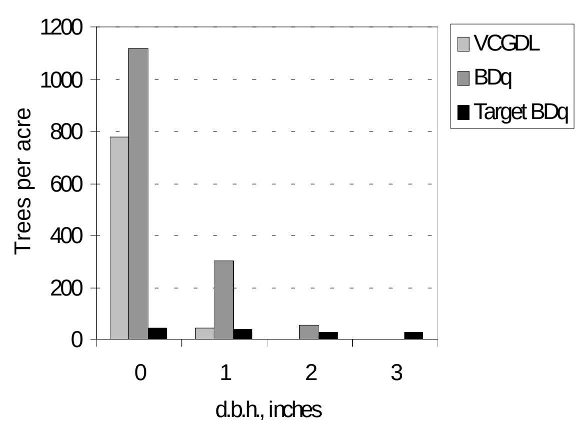

Figure 7—Regeneration density for two uneven-aged treatments compared to that expected based on the target BDq structure.

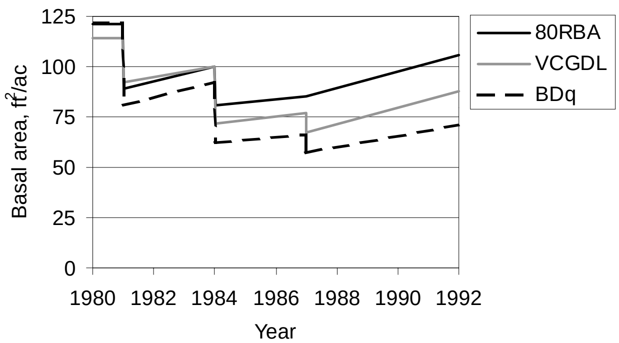

Figure 8—Basal area trends over the 12-year period by treatment.

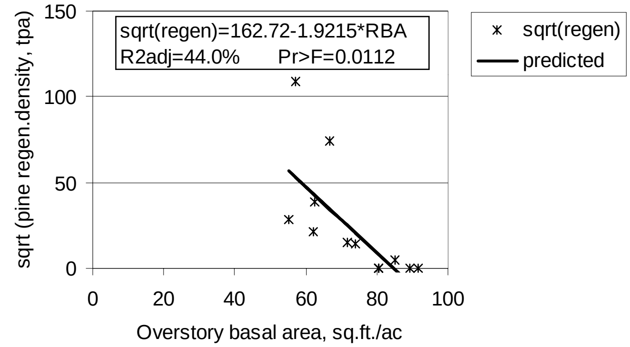

Figure 9—Relationship between before-cut basal area of trees 3.6 inches in d.b.h. and larger versus transformed regeneration density variable.

exceeded 70 percent and the BDq exceeded 80 percent. But by 1991-92, milacre stocking in both treatments had declined. At barely over 20 percent milacre stocking, the VCGDL treatment was marginal; whereas the BDq was acceptable at better than 30 percent milacre stocking.

A final way to judge whether regeneration density is adequate in uneven-aged stands is to compare observed density with that expected under the BDq target structure. The expected density can be calculated from the typical before-cut BDq parameters extended to the 0-inch, 1-inch, 2-inch, and 3-inch d.b.h. classes. Farrar (1996) suggests that the expected density derived in this way should be considered a minimum, and that two to three times that number should be present especially in the smaller size classes, since the rate of mortality of trees in the smaller size classes will be higher. In this demo, the BDq treatment is better than the VCGDL treatment in meeting or exceeding expected numbers by size class (figure 7), although neither treatment has produced adequate regeneration density in the 3-inch class after 12 years.

Basal Area of Different Treatments

High basal area in these treatments also may have adversely affected regeneration development. The BDq treatment was the only one in which after-cut residual basal area fell below 60 square feet per acre, and it was also the only treatment in which basal area remained below 75 square feet per acre from 1984 to 1992 (figure 8). Experience with the Good and Poor Farm Forestry Forties suggests that the best compromise between overstory growth and understory development is to maintain basal area between 60 and 75 square feet per acre (Baker and others 1996, Farrar 1996). Pooling the before-cut inventory data from each treatment with regeneration density data suggested a significant inverse relationship that reinforces these observations (figure 9).

Another factor that may have affected pine regeneration development was the percentage of basal area in sawtimber. Again, experience from the Good and Poor Farm Forestry Forties and elsewhere suggests that from between two-thirds to three-quarters of the total after-cut basal area should be in the sawtimber size classes, which for those stands started with the 12-inch diameter class (Farrar and others 1984b). In these stands, the percentage of basal area in trees 11.6 inches d.b.h. and larger increased over the duration of the study, ultimately exceeding 75 percent in all treatments (table 2).

DISCUSSION

The successful establishment and development of the desired species of regeneration is critical to the success of uneven-aged systems. By this standard, the BDq method was the only successful treatment over the 12-year conversion interval. The VCGDL treatment also exceeded these minimal standards, but only barely; if one tallied only the 1-inch and larger stems, this treatment had a stem density too low to be considered a success.

Conversion from even-aged to uneven-aged conditions is a long process. In 1986-87, both uneven-aged treatments had more than 5,000 stems per acre in the regeneration size classes. However, an additional 6 years of growth led to a prominent reduction in the number of stems in the regeneration size class, especially in the VCGDL treatment with its higher overstory basal area.

After 1987, the original planted trees and one cohort of regeneration had become established. Recruitment of a third age cohort would depend on continued cutting-cycle harvests in the overstory, and these harvests would have to be sufficiently intensive to create growing space for the establishment of new seedlings. But it would be hard to assert that the uneven-aged treatments had, after 12 years, resulted in three distinct age classes.

Suspicion that the process of converting plantations from even-aged to uneven-aged structure is inefficient has not been borne out a 12 year period in this demo. All three treatments had 12-year periodic annual increment exceeding 80 cubic feet per acre in total merchantable and sawtimber cubic volume, 450 board feet per acre Doyle, and 600 board feet per acre International ¼-inch rule.

It might appear anomalous for total merchantable cubic volume PAI to be lower than sawtimber cubic volume PAI. This is attributed to ingrowth into the sawtimber component. Murphy and Shelton (1994) reported similar

results. When a tree grows past the 9.6-inch threshold, its sawtimber cubic volume goes instantly from 0 to 6.7 cubic feet, a growth of 6.7 cubic feet. Conversely, its total merchantable cubic volume goes from 10.8 to 14.1 cubic feet, a growth of 3.3 cubic feet. Thus, if ingrowth is high, as it is in this study, sawtimber cubic volume PAI can exceed that of total merchantable cubic volume PAI.

At some point in the life of these plots, volume increment of the original plantation cohort will decline. At another point, the new cohort of trees established during this 12-year period will make contributions to the stand-level PAI. Whether those two points will occur in synchrony to maintain PAI at the levels reported from this 12-year period remain to be seen, but one would suspect that the first point will be reached before the second—and thus that there will be a shortfall in PAI in the next decade or two.

Implications in the distribution of basal area in the sawtimber component are not clear. It has been suggested that the high shade from the crowns of overstory trees alone provide less competition to understory development than an equivalent amount of low shade cast by midstory trees alone (Baker and others 1996). But in this demonstration the opposite appears to be the case, because the treatments with highest percentage of RBA in sawtimber (the 80 RBA and the VCGDL) are those with the least amount of regeneration. The lack of pine regeneration in these two treatments may have resulted from the prescribed burning in the 80 RBA treatment and the generally high levels of residual basal area in both treatments. Some replicated comparisons of regeneration establishment and development beneath pure sawtimber stands versus stands of mixed sawtimber and pulpwood size classes having the same basal area would shed some light on this point.

Finally, this demonstration clearly reveals an important point about converting stands from even-aged to uneven-aged structure using single-tree selection. It is not a rapid process. After 12 years, one of these uneven-aged treatments is headed in the right direction, and the other is marginal. Another decade or two will be needed to judge whether either of these conversion treatments was successful, with new cohorts of regeneration established in sufficient density and stocking, and making acceptable diameter growth into the pulpwood and sawtimber size classes. Additional time will also be needed to determine whether there are unacceptable declines in volume increment over time. Based on this understanding, foresters who plan to undertake the conversion of an even-aged stand to uneven-aged conditions should do so only if they can commit appropriate time to the conversion; time that is more likely to be measured in decades rather than years.

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