LOGGING DAMAGE TO RESIDUAL TREES FOLLOWING COMMERCIAL HARVESTING TO DIFFERENT OVERSTORY RETENTION LEVELS IN A MATURE HARDWOOD STAND IN TENNESSEE

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Abstract—Partial cutting in mature hardwood stands often causes physical damage to residual stems through felling and skidding resulting in a decline in bole quality and subsequent loss of tree value. This study assessed the logging damage to residual trees following commercial harvesting in a fully stocked, mature oak-hickory stand cut to three overstory basal area retention levels: 12.5, 25, and 50 percent. These treatments were replicated three times in north-facing, south-facing, and ridgetop blocks. The logging operation caused widespread damage to residual trees, with more than 76 percent of the trees experiencing some logging damage regardless of treatment and 45 percent of bole-damaged trees rated as severe damage that would ultimately decrease the future value of the tree. More tree damage occurred at the greater basal area retention levels. After 2 years, bole degrade associated with the formation of epicormic branches was much less compared to the bole damage caused by the physical abrasion from the harvesting operation. Potential damage to retention trees should be considered when evaluating silvicultural options where increasing value of retention trees is an objective.

INTRODUCTION

Public distaste with clearcutting has led forest managers to seek management and regeneration alternatives. One possible alternative is the two-age system where two distinct age classes are maintained for the majority of the rotation (Nyland 1996). The system is initiated by treatments which retain a limited number of canopy or reserve trees from the previous stand along with a cohort of developing, younger stems. These two ages are allowed to develop together to form a two-aged stand (Beck 1986).

Typically, a two-age stand is created by using a partial cut where a limited number of reserve trees, occupying 10 to 30 square feet of basal area (BA) per acre, are retained. These trees have characteristics (good form, greater than average diameter growth, better log grades, and longevity) advantageous to remain for a second rotation and to increase in value without compromising the regeneration or development of the younger cohort (Miller and Schuler 1995). Although this system has often been termed shelterwood with reserves or irregular shelterwood, the term shelterwood is misleading. The reserve or retention trees are not intended to provide any "sheltering" effect to the regeneration (Stringer 2002). The few remaining canopy trees provide an aesthetic alternative to clearcutting, increase in value, remain in place for another rotation, maintain some mast production for wildlife and seed for reproduction, and are widely spaced so that they do not hinder the developing younger age class.

Forest managers often fail to use partial or deferment cuttings in fully stocked hardwood stands because of the potential of logging damage to highly valued retention or leave trees during the harvesting operation. Retention trees are also subject to the development of epicormic branches, which degrades the bole quality (Meadows 1993). Bole quality, as defined by log grade (Rast and others 1973), is the most important factor in determining value of a hardwood log. In general, Stubbs (1986) estimated that USDA Forest Service log grades 1, 2, and 3 have value ratios of approximately 13:7:1, with butt logs much more likely to produce the better log grades than upper logs. Any damage to the butt log of retention trees during the harvesting operation or with the formation of epicormic branches would likely lower the log grade and its potential value.

To address the concern about potential tree damage associated with logging operations during partial cutting in fully stocked stands, this study evaluated the damage to residual trees 2 years after various partial cutting treatments in upland hardwood stands in eastern Tennessee. Specific objectives were (1) to determine the amount of logging damage and formation of epicormic branches on residual trees retained at three BA retention levels (12.5, 25, and 50 percent), and (2) to assess the severity and type of damage on residual trees associated with the different levels of harvesting.

METHODS

Study Area

This study was conducted at the University of Tennessee Forestry Experiment Station in Oak Ridge, TN. It is one of several multi-dimensional studies located on the same area to evaluate effects of different levels of overstory retention on growth and development of regeneration (Barwatt and others 2006, Olson 2003). Treatment blocks were established within a 75-acre oak-hickory forest that had experienced minimal disturbance since 1935. Aerial photography taken in 1935 by the Tennessee Valley Authority (TVA) indicated that the study area was forested at that time. Soils are moderately productive (site index for white oak at 50 years ranges from 65 to 75 feet) and belong to the Fullerton soil series.

Experimental Design

A randomized complete block design was used in this experiment. Three blocks containing all the treatments were delineated based on stand structure, forest composition, and landscape position. Analysis of variance indicated significant differences in pre-harvest BA among the three blocks (*P*<0.05), which justified blocking (table 1). Variation between the blocks was primarily due to topographic position and aspect. Treatments were randomly assigned to 4 acre plots and harvesting

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Table 1—Mean basal area for the three replicate blocks for the logging damage study at the University of Tennessee Forestry Experiment Station, Oak Ridge, TN

Replicates	Basal area[a]
	$ft^2 acre^{-1}$
Rep #1 (north)	126a
Rep #2 (ridge)	112ab
Rep #3 (south)	88b

[a] Means with different letters are significantly different at p=0.05.

took place in May and June, 2002. Treatments were based on varying degrees of BA retention: 50, 25, and 12.5 percent.

Stands with the 50, 25, and 12.5 percent BA retention were marked for commercial harvest with the general guideline of creating uniformly distributed stands comprised of desirable species. Common overstory species on the study area were white oak (*Quercus alba* L.), chestnut oak (*Q. prinus* L.), yellow-poplar (*Liriodendron tulipifera* L.), hickories (*Carya* spp.), northern red oak (*Q. rubra* L.), black oak (*Q. velutina* Lam.), southern red oak (*Q. falcata* Michx.), red maple (*Acer rubrum* L.), sugar maple (*A.* saccharum Marsh.), American beech (*Fagus grandifolia* Ehrh.), blackgum (*Nyssa sylvatica* Marsh.), and shortleaf pine (*Pinus echinata* Mill.). Guidelines for selecting desirable leave trees included: (1) proper species with capability of growing and surviving for another 50 years (white and chestnut oak and yellow-poplar were preferred), (2) dominant or codominant crown class, and (3) probability of value increase. Trees in the 14 to 18 inch d.b.h. category were favored for retention, but trees in other size classes and perhaps of less desirable species such as hickory and red maple were retained as necessary to maintain an even distribution across all the treatment units (Olson 2003). Blocks one, two, and three were located on a north-facing slope, flat ridge top, and south facing slope, respectively. Plots within blocks were generally arranged in a linear fashion, parallel to the contour of the slope.

Treatment Implementation

A commercial timber sale using competitive bids was used to harvest the timber. Even though the harvest took place on a research area, we did not try to influence who would submit the successful bid. We wanted to simulate a sale and harvesting procedure that would be common on most private lands in the area. The leave trees were marked, and the timber harvester was responsible for cutting all unmarked trees. The successful buyer subcontracted the timber to a local logging firm who had not harvested timber on the experiment station previously. The loggers were given very little guidance on how to harvest the timber except for where to locate log landings, primary skid trails, and haul roads. The contract specified that best management practices (Tennessee Department of Agriculture, Division of Forestry 2003) be implemented.

Data Collection

Each leave tree for every treatment for the three blocks or replicates was visited after the harvest during the fall of 2002 to survey for potential tree damage to the bole and the crown. Trees were classified as damaged, destroyed (if tree was dead or pushed over because of logging damage), or unaffected. The type of damage, whether to the bole, crown, or both, was catalogued. The severity of bole damage (severe, moderate, or minor; see definitions in table 2) was noted. We did not measure or quantify the size of the damage. During the winter of 2004, each tree was visited again to verify the damage code collected in 2002 and to count trees which had epicormic branch formation on the lower 16-foot butt log. Epicormic branches were defined as those that had initiated after the timber harvest and were at least 1 foot long and 3/8 inches in diameter at the bark surface (Meadows and Burkhardt 2001).

RESULTS

Number of Trees Retained by Treatment

The total number of retention trees remaining after the harvesting operation and sampled in this study (summed for each treatment across blocks) was 62, 159, and 307 for the 12.5, 25, and 50 percent BA retention treatments, respectively (table 2). Mean diameter of the retention trees was essentially the same across treatments at 16 to 17 inches.

Logging Damage to Residual Trees

The logging operation caused widespread damage to residual trees. More than 43 percent (27/62) of the trees in the 12.5 BA treatment were classified as damaged or destroyed by the harvesting operation (table 2). The remaining trees, 35, were not damaged by logging. However, more damage, approximately 80 percent of the trees, was found in the 25 and 50 percent BA retention treatments. More trees were damaged as the number of trees retained increased. Few trees remained that were not damaged in these two treatments.

Type of Logging Damage

Excluding the number of destroyed trees, totaling 16, 13, and 11 percent of the trees sampled for the 12.5, 25, and 50 BA retention treatments, most of the damage to trees was associated with the bole (table 2). The percentage of bole-damaged trees ranged from 64 to 72 percent by treatment. Crown damage was much less, averaging about 20 percent of the damaged trees for each treatment. Trees sustaining both bole and crown damage was < 12 percent for each treatment.

Severity of Logging Damage to Tree Boles

Most of the bole damage ("bole damage" and "both" categories) was rated as severe (reduction of one log grade) with 54, 45, and 44 percent of bole-damaged trees for the 12.5, 25, and 50 percent BA retention treatments, respectively (table 2). About a third of the bole-damaged trees, regardless of treatment, received the minor rating where bole damage did not reduce log grade. The moderate rating ranged from 15 to 23 percent of the bole-damaged trees.

Formation of Epicormic Branches

Few epicormic branches developed on the butt log of retention trees after 2 years (table 2). Based on the total number of damaged and unaffected retention trees, only 10 percent of the trees had epicormic branches for the 12.5 and 50 percent

Table 2—Tree damage comparisons at different basal area retention levels summed for each treatment across blocks for the logging damage study at the University of Tennessee Forestry Experiment Station, Oak Ridge, TN

	Basal area (BA) retention treatment		
	12.5% BA	25% BA	50% BA
Retention trees			
Total number by treatment	62	159	307
Average diameter (*inches*)	16.0	17.0	17.1
	- - - - - - - *number of trees* - - - - - - -		
Damage classification[a]			
damaged	17	106	214
destroyed	10	21	34
unaffected	35	32	59
Type of damage			
bole	11	76	147
crown	4	19	40
both	2	11	27
Severity of bole damage[b]			
Severe	7	39	77
Moderate	2	20	34
Minor	4	28	63
Epicormic branches after 2 years[c]	5	18	29

[a] Damaged = visible damage of tree crown or bole or both from harvesting operation; destroyed = tree completely lost during harvesting operation; unaffected = no visible damage to tree.
[b] Severe = bole damage causes log grade to decrease by at least one grade; moderate = bole damage has the “potential” to cause log grade to decrease by at least one class, however, log grade does not change at present; minor = slight bole damage that does not change log grade.
[c] Counted on the 16-foot butt log only.

BA retention levels, with 13 percent of the trees for the 25 percent BA retention treatment.

DISCUSSION

One of the potential difficulties of partial harvesting in any stand is logging damage to residual trees. Some damage is expected and inevitable, especially in mature, fully stocked stands. However, the harvesting operation monitored in this study caused widespread damage to the residual stand, with more than 80 percent of the trees damaged in some manner in the 25 and 50 percent BA retention treatments (table 2) Much of this damage could have been avoided through more careful logging procedures. Most of the bole damage was from skidding when tree-length logs scraped against boles of standing trees on primary and secondary skid trails. Bark was often rubbed off, and roots near the base of the tree were often exposed. Also, better felling procedures, such as directional felling, could have remedied some of the crown damage. Many trees were cut without any regard to where they might fall. More tree damage occurred at the greater BA retention levels. Logging equipment was able to maneuver around widely spaced individual trees in sparsely stocked areas with less tree damage than in areas where trees were more closely spaced.

The number of trees that were destroyed by the harvesting operation ranged from 11 to 16 percent depending on the treatment. Although this percentage might seem of minor influence, losing more than 10 percent of overstory trees that will comprise the next stand will reduce the total value of the stand and represents an investment loss.

Logging damage was rated as severe for more than 44 percent of the bole-damaged trees in the 25 and 50 percent BA residual treatment and more than 54 percent in the 12.5 percent BA retention treatment. The severe classification represents damage so great that the log grade decreases by one grade on the butt log. The butt log is the most valuable log in the tree. This again devalues the remaining trees in the residual stand because the trees will probably not heal over and increase to a better log grade anytime in the foreseeable future. The logging wounds provide an opportunity for fungi to enter the tree and instigate the spread of wood decay and rot that will diminish the value of the tree (Shigo 1979, 1986). With the extensive damage incurred by these residual trees and their decrease in value by reduction in log grade, trees are devalued in the current stand and in the potential of the future stand. The damage classified as minor probably will not affect the value of the residual trees now or in the future. These wounds should heal over fairly quickly without having an effect on the log grade.

Damage from epicormic branches was not as much of a consideration as the bole or crown damage in this study. Less than 13 percent of the butt logs of residual stems were damaged by epicormic branching after 2 years regardless of treatment (table 2). Most of the stems with epicormics also had associated crown or bole damage, indications of stress that may have instigated formation of epicormic branches (Meadows and Burkhardt 2001). However, yellow-poplar was one of the desired species featured for residual leave trees, a species that does not have the propensity to form epicormic branches. More epicormics would be expected if more oaks, particularly white oaks, were left as residuals compared to yellow-poplar (Miller 1996).

CONCLUSIONS

More careful logging would have reduced the amount of residual stem damage associated with partial harvesting in this study. Some damage is acceptable, especially in fully stocked, large diameter stands. However, the greater BA retention levels increased the chance of bole and crown damage to residual trees. Thinnings and partial harvests have many advantages in reducing stand density, favoring certain species, increasing diameter growth, and having more pleasing aesthetics when compared to clearcutting. However, the potential detrimental damage to residual trees should be considered. Residual-tree damage from partial cutting may cause a decline in bole quality and subsequent loss of tree value. Reduction of butt log grade and the loss of potential tree value are prime considerations with long-term effects in the future stand.

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