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# DISTURBANCE FROM THE INITIAL HARVEST IMPLEMENTING UNEVEN-AGED SILVICULTURE IN A PINE-HARDWOOD STAND IN SOUTHWESTERN MISSISSIPPI<sup>1</sup>

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**Abstract**—Logging disturbance is important in uneven-aged stands because harvests are frequent, merchantable trees are retained, and regeneration may be present. Logging disturbance was monitored during the establishment of a study testing the application of uneven-aged silviculture in an irregularly aged, pine-hardwood stand. Disturbances were: (1) seedbed conditions averaging 58, 16, 9, and 17 percent of the area in undisturbed litter, disturbed litter, mineral soil, and logging slash, respectively, (2) a 44 percent reduction in the number of submerchantable hardwood stems, and (3) mortality or severe damage of retained merchantable trees of 1.0 stem per acre for pines and 2.7 stems per acre for hardwoods. Pine regeneration 1 year after harvesting was significantly affected by the seedbed conditions existing after the harvest. Exposed mineral soil and disturbed litter increased the number of seedlings, while the effects of fine logging slash were negative.

## INTRODUCTION

Most knowledge about the uneven-aged silviculture of loblolly (*Pinus taeda* L.) and shortleaf (*P. echinata* Mill.) pine was accumulated over a 50-year period at the Crossett Experimental Forest in southeastern Arkansas (Reynolds 1959, Reynolds and others 1984). Uneven-aged silviculture was used to rehabilitate understocked, cutover stands that already had somewhat of a reverse-J size-class distribution. Crossett guidelines call for aggressive competition control and periodic harvests to favor pine regeneration and provide acceptable growth and yield rates. Harvesting is one of the principal stand disturbances in uneven-aged stands, and it is the way that stocking of merchantable trees is regulated. Some of the impacts of harvesting benefit stand regeneration, such as creating favorable seedbed and environmental conditions and destroying some of the competing vegetation. However, other effects are harmful, such as damage to both regeneration and merchantable trees. To determine potential disturbance levels from logging uneven-aged stands, we monitored the conditions existing before and after the harvesting operation implementing a study testing uneven-aged silviculture in a pine-hardwood stand.

## METHODS

### Study Site

The study was installed in a mature, second-growth pine-hardwood stand in the Homochitto National Forest in Franklin County, Mississippi. Soils in the study area are mapped as the Lorman series (Vertic Hapludalfs), which has a silty loam surface horizon and a clayey subsurface. The site is in the Southern Pine Hill physiographic district. Elevations ranged from 200 to 260 ft above sea level. Plots were located on the side slopes in an area of undulating topography, and slopes ranged from 8 to 15 percent. The basal area of merchantable (d.b.h.  $\geq 3.6$  inches) pines averaged 81 ft<sup>2</sup> per acre before harvest, with two-thirds consisting of shortleaf pine and one-third loblolly pine. Basal areas averaged 32 ft<sup>2</sup> per acre for merchantable hardwoods.

### Study Design and Treatment Implementation

Eighteen square, 0.5-acre plots were installed and surrounded by a 58.2-ft isolation strip that received the same treatment. Treatments reduced merchantable basal area to two levels for pines (45 and 60 ft<sup>2</sup> per acre) and three levels for hardwoods (0, 15, and 30 ft<sup>2</sup> per acre). Treatments were assigned in a completely random design with three replications for each pine-hardwood combination.

The pine harvest was implemented using the basal-area maximum-diameter quotient technique of single-tree selection (Baker and others 1996). Guidelines were for a maximum diameter of 24 inches and a quotient of 1.2 for 1-inch d.b.h. classes. Guidelines for maximum diameter and quotient were followed as closely as feasible because the stand lacked a balanced reverse-J structure. Hardwood retention favored the larger and higher quality red and white oaks.

The study area was harvested in dry weather during September and early October of 1990. Primary skidtrails were located along the crest of long, narrow ridges that extended through the study area, with secondary skidtrails extending downslope. Because plots were located on the side slopes, trees from one plot were not skidded through another, which isolated the harvesting impacts for individual plots. Loggers used two rubber-tired cable skidders with 120 horsepower engines. Logs were skidded tree-length with no special restrictions imposed. Harvested volume of merchantable pines averaged 998 ft<sup>3</sup> per acre and ranged from 0 to 2,400 ft<sup>3</sup> per acre for individual plots. Harvested pine sawtimber averaged 4,140 board ft Doyle per acre. This was a relatively high volume because it was the initial application of uneven-aged silviculture. Harvested volumes in uneven-aged stands on good sites will typically range from 1,200 to 4,000 board ft Doyle per acre depending on the cutting-cycle length (Baker and others 1996).

<sup>1</sup> Paper presented at the Tenth Biennial Southern Silvicultural Research Conference, Shreveport, LA, February 16-18, 1999.

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## Measurements and Data Analysis

Before harvesting (April 1990), tree saplings and shrubs (0.6 to 3.5 inches d.b.h.) were counted by 1-inch d.b.h. classes on 36 temporary 0.01-acre plots systematically located across the study area. After harvesting (October 1990), 10 permanent monitoring points were systematically located within each 0.5-acre plot. Points were at least 30 ft from the interior plot boundary and 88 ft from the exterior plot boundary. Seedbed conditions were evaluated at 12 points along a 24-ft line-transect centered around each permanent monitoring point. Visual estimation of seedbed coverage in a milacre plot around each permanent point provided values for comparison with regeneration inventories. Each evaluation used the same classification system for seedbed conditions: (1) undisturbed litter, (2) disturbed litter, (3) exposed mineral soil, (4) fine logging slash  $\leq 0.5$  inches in diameter (foliage and twigs), (5) medium logging slash from 0.6 to 4.0 inches in diameter (mainly branches), and (6) coarse logging slash  $\geq 4.1$  inches in diameter (chiefly stems).

Submerchantable trees  $\geq 1$  inch d.b.h. were inventoried after harvesting on 0.01-acre plots at half of the permanent monitoring points. The purpose of this inventory was to determine the number of hardwood stems that were to be treated with herbicides. Any stem that would be treated during hardwood control was counted, even if it had been severely damaged. Retained merchantable trees in the 0.5-acre plot were inspected after logging for damage and defects. In September 1991, pine seedlings from the 1990 seed crop were counted on milacre plots centered around each of the 10 permanent monitoring points.

Mean values were calculated for measurements from the 10 permanent monitoring points within each 0.5-acre plot. Harvested volumes were calculated from the marking tally for each 0.5-acre plot, according to the procedure of Farrar and Murphy (1988) for pines, and Clark and others (1986) for hardwoods. Merchantability limits were: (1) trees  $\geq 10$  inches d.b.h. and to an 8-inch outside-bark top for pine sawtimber, (2) trees  $\geq 5$  inches d.b.h. and to a 4-inch outside-bark top for pine pulpwood, and (3) trees  $\geq 6$  inches d.b.h. and to a 4-inch outside-bark top for hardwood pulpwood.

Data were analyzed by nonlinear least squares regression using the SAS procedure MODEL (SAS Institute 1988). Coefficients of variables included in models significantly differed from zero at a probability level of  $\leq 0.10$ .

## RESULTS AND DISCUSSION

### Seedbed Conditions

The most widespread seedbed condition was undisturbed litter, which accounted for 58 percent of the area (table 1). Most of the soil surface after harvesting was covered by some type of organic material, and only 9 percent of the area was exposed mineral soil. Although a mineral soil surface promotes pine seedling establishment, this relationship must be considered within the goal of securing acceptable regeneration. For example, acceptable pine regeneration will become established on litter seedbeds if the seed supply is sufficient (Cain 1991). In addition, Shelton (1995) pointed out that litter seedbeds are often beneficial because they reduce competing vegetation and prevent pine overstocking.

Because harvested volumes varied among 0.5-acre plots, the relationship between seedbed conditions and harvesting

Table 1—Mean and range for seedbed conditions after the initial harvest implementing uneven-aged silviculture in a pine-hardwood stand

Seedbed condition	Mean	Minimum	Maximum
-- Coverage (percent of area) --			
Undisturbed litter	58	34	79
Disturbed litter	16	4	28
Logging slash	17	2	36
Mineral soil	9	2	14

intensity could be determined. Harvested volumes significantly affected all seedbed conditions except exposed mineral soil (table 2). Fit indices ranged from 0.27 to 0.61.

The area of undisturbed litter was negatively related to the harvested volumes of pines and hardwoods, which explained 60 percent of the variation in this relationship. The area in undisturbed litter was calculated from regression coefficients; values are plotted in figure 1. Undisturbed litter covered 66 percent of the ground surface when the pine harvest was 500 ft<sup>3</sup> per acre and no hardwoods were harvested. Undisturbed litter decreased to 36 percent when the harvested pine and hardwood volumes were 2,400 and 400 ft<sup>3</sup> per acre, respectively.

The area of disturbed litter increased with the volume of harvested pines, which explained 28 percent of the variation (table 2). Hardwood volume was not significant, which may reflect these species relatively low contribution to the total harvested volume (11 percent). The area of disturbed litter increased from 14 percent when 500 ft<sup>3</sup> per acre of merchantable pines were harvested, to 23 percent when 2,400 ft<sup>3</sup> per acre were harvested (fig. 1).

The area covered by logging slash increased with the volume of harvested hardwoods, explaining 61 percent of the variation (table 2). Coverage increased from a base level of 11 percent, which reflects the contribution of pines to logging debris (fig. 1). About 32 percent of the area was covered by logging slash when the volume of harvested hardwoods was 400 ft<sup>3</sup> per acre. The high contribution of hardwoods to logging slash undoubtedly reflects their large, deliquescent crowns when compared to the excurrent crowns of the pines. Hardwoods in this study had crown volumes that were about twice as large as pines of the same d.b.h. Most of the area covered by logging slash was attributable to fine slash (71 percent), while the remainder was medium (23 percent) and coarse slash (6 percent). The contribution of fine slash would have been much lower had the harvest been conducted during the dormant season. This seasonality can be used to reduce the visual impacts of the harvesting, especially when the hardwood volume is high.

Uneven-aged silviculture is characterized by frequent, low-intensity harvests. There has been little research concerning the levels of soil disturbance associated with the cycle cuts in uneven-aged stands. Harvested volumes in this study were at the upper end of the range for typical cycle

**Table 2—Regression coefficients and associated statistics for the relationships between seedbed conditions after harvesting and the harvested volumes for the initial application of uneven-aged silviculture in a pine-hardwood stand**

Seedbed condition	Regression coefficients <sup>a</sup>			Root mean square error	Fit index
	b <sub>0</sub>	b <sub>1</sub>	b <sub>2</sub>		
Undisturbed litter	4.26	-0.133	-0.859	10.7	0.60
Disturbed litter	2.52	.254	Ns <sup>b</sup>	5.7	.27
Logging slash	2.43	Ns	2.557	7.5	.61
Mineral soil	Ns	Ns	Ns	—	—

<sup>a</sup> The equation is:  $SB = \exp(b_0 + b_1PVOL + b_2HVOL)$ , where SB is the area covered by the specified seedbed condition in percentage, and PVOL and HVOL are the harvested pine and hardwood merchantable volumes, respectively, in 1,000 ft<sup>3</sup> per acre.

<sup>b</sup> Variables were dropped from regressions if their coefficients did not significantly (Ns) differ from zero at P ≤ 0.10.

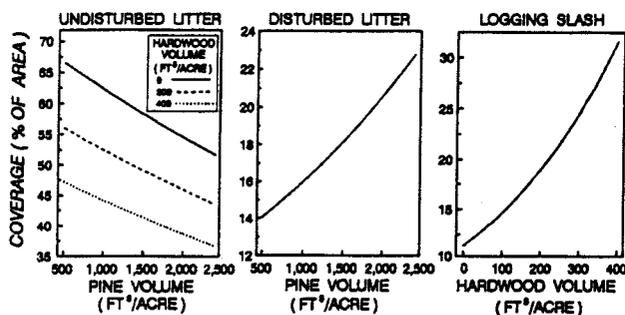


Figure 1—Effects of harvested volumes on seedbed conditions after the initial harvest implementing uneven-aged silviculture in a pine-hardwood stand. Values calculated from regression coefficients in table 2.

cuts in uneven-aged stands, and the resulting disturbances probably also would be high. Kluender and others (1994) reported similar levels of disturbance for the initial harvest applying uneven-aged silviculture in pine-oak stands in the Ouachita Mountains; means were 42 percent of the area for undisturbed litter, 26 percent for disturbed litter, 12 percent for logging slash, and 10 percent for mineral soil. Soil disturbances from these initial harvests applying uneven-aged silviculture are considerably lower than those reported for even-aged reproductive cutting methods. For example, strip clearcutting a loblolly pine stand in the Coastal Plain of Virginia resulted in 34 percent of the area undisturbed, 49 percent disturbed, and 17 percent covered by slash (Pomeroy and Trousdell 1948). In loblolly-shortleaf pine stands of southern Arkansas, Grano (1971) observed that a seed-tree cut removing 5,600 board ft International per acre and 6 cords per acre of pulpwood exposed 25 percent of the surface to mineral soil.

### Pine Seedling-Seedbed Relationships

The number of pine seedlings after the first growing season was significantly related to seedbed conditions existing after harvest as shown by the following equation:

$$N = \exp(3.29 + 0.0136MS + 0.00709DL - 0.0184FLS) \quad (1)$$

In this equation, *N* is the number of seedlings per milacre; *MS*, *DL*, and *FLS* are the percentage of the milacre in exposed mineral soil, disturbed litter, and fine logging slash, respectively. Fit index for the equation was 0.16, root mean square error was 36.4, and there were 176 degrees of freedom. The effects of mineral soil and disturbed litter were both positive, while the effects of fine logging slash were negative. Coverage of fine logging slash was a better predictor than coarser size classes or total slash. This relationship reflects the well-known seedbed requirements for establishment of loblolly and shortleaf pine seedlings: mineral soil is the most favorable seedbed condition, while deep accumulations of organic materials are the least favorable (Shelton and Wittwer 1992). However, conditions are rarely so unfavorable that no establishment occurs, especially if seed production is high (Grano 1949).

The seedbed conditions existing when pine seeds are dispersed affect the percentage of seeds that germinate and become established. To show this relationship, equation (1) was solved for a reasonable range of seedbed conditions (fig. 2). The bumper seed crop of 1990 (1.5 million sound seeds per acre) resulted in 15 seedlings per milacre where seedbed conditions were poorest and 50 seedlings per milacre where conditions were most favorable. The seedling-to-seed ratio in the former was 1.0 percent and 3.3 percent in the latter. However, independent variables in equation (1) explained only 16 percent of the variation in seedling density. This finding demonstrates that seedbed conditions interact with many other factors to determine the successful establishment of pine regeneration.

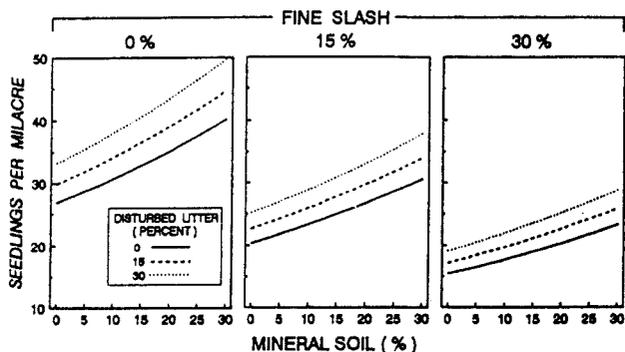


Figure 2—The relationship between seedbed conditions after the initial harvest implementing uneven-aged silviculture in a pine-hardwood stand and the number of pine seedlings 1 year later. Values calculated from equation (1).

### Vegetation Damage

Harvesting had a substantial effect on the number of submerchantable hardwoods (fig. 3). Before harvest, there were 730 stems per acre in the submerchantable classes (1 to 5 inches d.b.h.), which were reduced by 44 percent during harvest. In this evaluation, stems were counted if they required treatment with herbicides applied by frilling and cut-surface application; many stems were damaged but would still be treated. Losses varied substantially with stem size. Nearly 75 percent of stems in the 1-inch d.b.h. class were lost, but almost no stems  $\geq 3$  inches d.b.h. were lost. Some submerchantable hardwoods were cut for access to merchantable trees; other stems were broken or uprooted during felling and skidding.

Harvesting provided a partial mechanical control of submerchantable hardwoods, which had both beneficial and harmful effects. It reduced the number of stems to be treated with stem-injected herbicide, but many of these stems were only top killed and would sprout. Because of the sprouting of top-killed hardwoods, Cain (1988) reported that stem-injected herbicides are more effectively applied before harvesting than after.

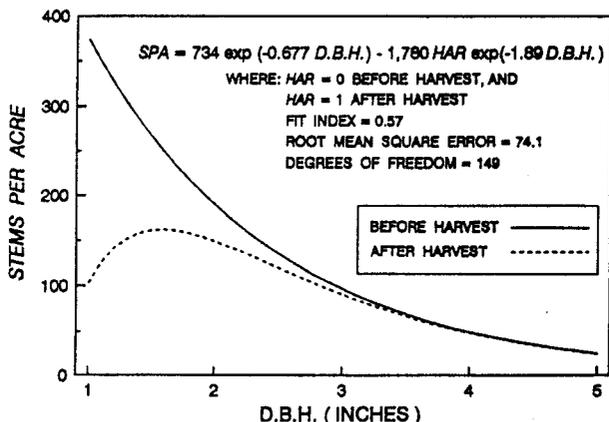


Figure 3—Effects of the initial harvest implementing uneven-aged silviculture in a pine-hardwood stand on the number of submerchantable hardwood stems (SPA).

Tree mortality or life-threatening damage during harvesting averaged 1.0 trees per acre for retained merchantable pines and 2.7 trees per acre for hardwoods. Most of these trees were in the smaller diameter classes, and their stems and/or tops were broken by felled sawlog trees. Skidding produced very little scarring to the boles of residual trees. Only 1.4 pines per acre and 1.3 hardwoods per acre were classified as having bole scarring as their major defect after harvest. However, these values may underestimate the actual amount of scarring if the tree was classified as having another, more limiting defect.

### MANAGEMENT IMPLICATIONS AND CONCLUSIONS

Frequent harvesting is an important component of the successful management of loblolly and shortleaf pines in uneven-aged stands. The logging disturbance evaluated in this study had both beneficial and detrimental effects. Logging exposed mineral soil and disturbed the forest floor, which increased the number of pine seedlings. However, logging also created slash, which suppressed pine seedling establishment. Logging provided partial, mechanical control of submerchantable hardwoods. This reduced the number of hardwoods to be chemically treated during competition control, but it may also result in future problems from sprouting hardwoods. Only a few of the retained merchantable trees were damaged during harvesting.

Results of this study suggest a high potential damage to pine regeneration during periodic harvests in uneven-aged stands. Thus, particular care is needed in stands lacking good structure in merchantable size classes but with a cohort of developing regeneration, which is critical in developing a well-structured stand in the future. Less attention is needed in stands without regeneration or in stands with good structure in merchantable size classes. In many cases, regeneration may be excessive in uneven-aged pine stands, and logging provides a degree of precommercial thinning. Logging damage can be reduced by using careful planning, experienced loggers, directional felling, in-the-woods branch and top removal, shorter log lengths, mid-sized skidding equipment, and dry-weather skidding. Group selection may have some advantages over single-tree selection regarding potential logging damage to regeneration, because the distinctive openings are easily seen and avoided.

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