United States
Department of
Agriculture

Forest Service

**Southern Forest
Experiment Station**

New Orleans,
Louisiana

Research Paper
SO-188
March, 1983

# Reinvasion of Hardwoods Following Eradication in an Uneven-Aged Pine Stand

M. D. Cain and D. A. Yaussy

## SUMMARY

Annual application of mechanical and chemical treatments for 12 years only temporarily eradicated hardwood species from an uneven-aged loblolly (*Pinus taeda* L.)/shortleaf (*P. echinata* Mill.) pine stand in south Arkansas. Eighteen years after treatments ended, an abundance of woody shrubs and hardwood trees had reinvaded the stand and denoted an early stage in successional development from pine to hardwood when compared to four other stands managed at various intensity levels.

# Reinvasion of Hardwoods Following Eradication in an Uneven-Aged Pine Stand

M. D. Cain and D. A. Yaussy

## INTRODUCTION

Throughout the South, forest managers encounter the problem of shade-tolerant understory species competing with pines for growing space, sunlight, moisture and nutrients. Hardwood competition in the understory can substantially reduce the growth of loblolly pine in mature natural stands (Grano 1970), young natural stands (Clason 1978), and young plantations (Cain and Mann 1980). In the southern region, estimates report that between two-thirds and three-fourths of the forests have problems with herbaceous plants, woody vines, shrubs and hardwood trees (Fitzgerald, Peevy and Fender 1973).

Hardwoods are less desirable than pines as a timber resource on most upland Coastal Plain sites. On southern pine sites they are slow growers, often scarred with short and crooked boles, highly variable in species composition within stands, with low volumes per acre that increase harvesting costs (Karchesy and Koch 1979). Consequently, suppression of these noncrop species is important to southern pine management. Nevertheless, certain characteristics that categorize hardwoods as undesirable timber make them preferred species for wildlife, recreation and aesthetics.

When hardwoods are controlled to increase pine production, many public interest groups, environmentalists and wildlife enthusiasts often object. Terminology such as "monoculture" or "biological desert" is often applied to stands of pure pine that lack species diversity (Popovich 1980). Although complete eradication of competing vegetation may be the ultimate goal of forest managers, Walstad (1976) noted that such an effort may be undesirable from both the economic and ecological standpoint.

Since hardwood control is widely practiced in southern pine management, it is appropriate to investigate the consequences of temporary eradication of hardwoods from pine sites in terms of species diversity. In 1951, Reynolds (1956) initiated a 12-year study on an upland loblolly/shortleaf pine site in south Arkansas to determine hardwood reinvasion associated with annual hardwood eradication. The present paper quantitatively describes the woody-plant component that resulted 18 years after eradication treatments ceased and compares the relative basal area, number and heights of individual species on the study area with those on four other areas receiving varying intensities of pine management and hardwood control.

## DESCRIPTION OF THE STUDY AREA

The study was located on the Crossett Experimental Forest, Ashley County, Arkansas, at 33°02'N mean latitude and 91°56'W mean longitude. Elevation of the area is about 53 m with a nearly level topography. Soils on the area are predominantly Bude (Glossaquic Fragiudalfs) and Providence (Typic Fragiudalfs) silt loam formed in thin loessial deposits and having an impervious layer at 46 to 102 cm that impedes internal drainage. Both soils have excellent potentials for pine growth with a site index of 27 m at 50 years. Annual precipitation averages 140 cm with extremes being wet winters and dry autumns. Daily temperatures average 23°C between March and September and 12°C between October and February.

## METHODS

### Establishment and Treatments in the Initial Study

In 1951, a 2.02-ha test area was selected for the hardwood eradication (HE) study within an uneven-aged loblolly/shortleaf pine stand of 16 ha which had been under selection management since 1939. Selec-

M. D. Cain is Associate Silviculturist, Southern Forest Experiment Station, Crossett, AR, and D. A. Yaussy is Associate Mensurationist, Northeastern Forest Experiment Station, Delaware, OH and formerly Southern Forest Experiment Station, Forest Service—USDA, Crossett, AR.

tion management is directed toward manipulation of diameter distribution to sustain periodic timber harvests (Murphy and Farrar 1981).

Within the test area, four treatment plots of 0.10 ha were established at random with interior 0.04-ha measurement subplots. Hardwood stocking prior to treatment was over 8,800 stems per hectare (table 1). In an effort to eradicate the hardwood competition, all woody stems larger than 8.8 cm dbh were girdled on study plots in the spring of 1951. The same treatment was applied to stands within a 402-m radius of the plots to eliminate the source of new seed from adjacent areas. On the four treatment plots, hardwoods 2.5 to 8.9 cm dbh were cut and Ammate crystals applied to the V-notch stump. Stems less than 2.5 cm dbh were sprayed with a water solution containing 240 g of 80 percent Ammate per liter.

Hardwood sprouts were again sprayed in the spring of 1952 with a 2 percent Ammate solution. In 1953 and continuing yearly through the spring of 1962, all hardwood regrowth was grubbed from the plots by hand. In July 1959, 2,4,5-T in diesel oil was sprayed at the rate of approximately 2.24 kg a.e./ha to reduce the heavy ground cover of vines, briars, grass, and weeds on study plots. Remaining hardwoods that had reached seed-bearing size on areas surrounding the plots were eliminated in the fall of 1960 by stem injection with 2,4,5-T in diesel oil.

Pine volume in the overstory averaged 111 $m^3$/ha or 19,800 fbm/ha[1] when the study was installed. Within three years of hardwood eradication, natural pine regeneration was abundant on all plots and had reached a 1.82 m height by 1956. Because of the influence that the pine regeneration might have on the initial study objectives, 3.05-m swaths were cut through the pine understory alternating with uncut strips of the same width. This mechanical thinning was done in the spring of 1957.

The last treatment for hardwood removal was done in the spring of 1962. Other than a selection pine cut over the entire 16-ha compartment in 1966, there had been no disturbance to the study area prior to a 1980 inventory when the overstory pine volume averaged 229 $m^3$/ha or 34,700 fbm/ha. Merchantable volumes were derived using local volume tables developed at the Crossett Experimental Forest. Board-foot volumes were computed by use of conversion factors (Reynolds 1959).

### Comparison Stands

Research on successional trends in the Southeastern Coastal Plain suggests that similarity of plant life in badly disturbed stands and relatively stable communities can be indicative of the ability of hardwood species to persist, even with mistreatment (Quarterman and Keever 1962). Consequently, the 1980 inventory on the HE plots was compared with data taken from four other stands on the Crossett Experimental Forest. In general, all pinelands within and contiguous to the Experimental Forest boundary had been cut to a 30 cm diameter limit by 1915. There were recurrent wildfires until fire protection began in the 1930's. A brief history of subsequent management for the four comparison stands follows:

*Unmanaged* (UM).—Since 1935 this stand of 32 ha has been reserved from management with the exception of fire protection and insect control. No harvesting has been done since 1915. Relative to the other comparison stands, this one has been unmanaged.

*Low Level of Management* (LM).—This 7-ha stand was part of a research study in which 3,000 pine seedlings per hectare were released in 1939 by cutting overstory hardwoods. Data used in this paper were taken where competing hardwoods $\geq$15 cm dbh were removed in 1939 during initial treatment. A 1949 thinning (10 to 30 cm dbh classes) removed 12 pines and 5 hardwoods per hectare. No other attempt to control hardwoods was made prior to a 1979 inventory. Relative to the other comparison stands, this one received a low level of management for pine and hardwood.

*Moderate Level of Management* (MM).—Since 1934, this 8-ha stand has had four improvement cuts, beginning in 1946 and at 5- or 6-year intervals until 1964. An average of 74 pines per hectare ranging from 10 to 76 cm dbh were removed in each improvement cut. Historical records do not indicate that hardwoods were ever removed or controlled in this stand. Relative to the other comparison stands, this one received a moderate level of pine management and no hardwood control.

*High Level of Management* (HM).—Pines in this 16-ha stand were managed from 1941 through 1965, during which time there were six harvest cuts. Each cut removed an average of 64 pines and 10 hardwoods per hectare that ranged from 10 to 51 cm dbh. In 1950 all residual hardwoods $\geq$10 cm dbh were girdled. In 1967 the stand was sprayed for hardwood control with 2,4,5-T in water solution at the rate of 2.24 kg a.e./ha using a tractor-mounted mist blower. Relative to the other comparison stands, this one received a high level of management for both pine and hardwood.

*Summary of HE and Four Comparison Stands.*—HE—Intensive pine management (four 9-year cycle-

[1]All board-foot (fbm) volumes are based on International ¼" log rule.

cuts plus twelve salvage cuts); complete eradication of hardwoods, 1951 through 1962. UM—No pine management; no hardwood control. LM—Low pine management (one improvement cut in 1949); hardwoods $\geq$15 cm dbh were removed in 1939 with additional thinning in 1949, but none thereafter. MM—Moderate pine management (four improvement cuts); no hardwood control. HM—Intensive pine management (six improvement cuts); hardwoods $\geq$10 cm dbh were periodically thinned prior to 1950 when residuals were girdled; hardwoods were sprayed with 2,4,5-T in 1967.

### Sampling Procedure

*HE Stand*—Original corners of the 0.04-ha interior plots were relocated in 1979. This was followed by an inventory of all overstory and understory woody stems in May 1980. Data were consolidated into one stand of 0.16 ha.

*UM Stand*—A set of 400 numbers, to represent 0.04-ha plots, were systematically assigned to a map for each of two 16-ha management units within this 32-ha stand. A random numbers table was used to select one number (plot) from each of the two management units for field location and inventory. Numbers assigned to the perimeter of the 32-ha stand were rejected to avoid edge effects. After plot establishment, an inventory of all overstory and understory stems was made in May 1980. Data were consolidated into one stand of 0.08 ha.

Understory inventories on the HE and UM plots were achieved by progressively covering 1.8-m wide transects across the width of each plot.

*LM, MM, and HM Stands*—Data from the LM, MM, and HM stands were obtained from plots established in conjunction with another study[2]. In the summer of 1979, one plot containing 0.2 ha was randomly established in each of these three stands. Within each 0.2-ha plot, 18 subplots of 8.09 $m^2$ each were selected by random assignment to low, medium, or high understory density levels. In the fall of 1979, an inventory of all stems less than 9.0 cm dbh on the 18 subplots produced the understory data for each stand. In the spring of 1980, an inventory of all stems larger than 8.9 cm dbh was taken on each 0.2-ha gross plot for overstory data.

### Measurements

Total heights of understory stems less than 9.0 cm dbh were taken to the nearest 0.3 m. Diameters of understory species were taken to the nearest millimeter at heights of 15 cm and 1.37 m. For overstory trees larger than 8.9 cm dbh, diameters were measured to the nearest 2.5 cm at 1.37 m. The species was identified for each stem measured (Little 1979).

### Data Analysis

Three criteria were used to assess the importance of and differences between understory species on the Hardwood Eradication (HE) plots and the four comparison stands. The criteria included:

$$\text{Relative basal area} = \frac{\text{Cross-sectional area at 15 cm for each understory species in the stand}}{\text{Cross-sectional area at 15 cm for all understory species in the stand}} \times 100$$

$$\text{Relative number} = \frac{\text{Number of understory stems for individual species in the stand}}{\text{Number of understory stems for all species in the stand}} \times 100$$

$$\text{Relative height} = \frac{\text{Mean height for individual understory species in the stand}}{\text{Sum of mean heights for all understory species in the stand}} \times 100$$

The overstory component of each stand was summarized in much the same way as the understory, except that only relative basal area and relative number were used. Relative basal area of overstory was calculated using basal area at dbh. These criteria were summed for individual species within a stand to obtain an Importance Value for comparing each species to others on the same area.

Importance Values were also used to calculate Simpson's index of dominance (Odum 1975) within stands and percent similarity (Monk 1967) between HE plots and the four comparison stands. The reciprocal of Simpson's index was computed and expressed as percent diversity so that the higher the value, the greater the diversity (table 3). For percent similarity (table 5), the possible range between stands is zero (stands having no species in common) to 100 (stands exactly identical). The midpoint (50 percent) of that range was chosen, prior to data analysis, as an indicator of stands being more similar than different.

## RESULTS AND DISCUSSION

### Hardwood Reinvasion on HE Plots

When the study was initiated in 1951, blackgum, oaks, sweetgum, and flowering dogwood comprised 90 percent of all understory hardwood stems (table 1). Other hardwoods included hickory, persimmon, red maple, sassafras, and elm. The 1951 pretreatment inventory totaled 8,854 stems per hectare for these understory hardwood species. In 1980 the most nu-

[2]Ku, T. T., J. B. Baker, and R. A. Williams, 1978. The use of understory vegetation as a renewable biomass energy resource. A Study Plan on file at the Department of Forestry, University of Arkansas at Monticello, Monticello, Arkansas.

merous hardwood tree species were oak, red maple, flowering dogwood, American holly, and elm. These totaled 2,948 stems per hectare and comprised 87 percent of the stocking for tree-type hardwoods. The 1980 inventory of hardwood trees represented about 38 percent of those found prior to treatment in 1951 and reflected an early stage in successional development.

When the understory was inventoried in the spring of 1962, after 11 years of annual hardwood eradication, there were 72 hardwood stems per hectare consisting of five woody species (table 1). In 1980, 18 years after treatments terminated, there were 8,633 stems per hectare including 24 species-groups of woody plants in the understory, excluding pine. For the five hardwood species on the site in 1962, there was a 30-fold increase in number of stems per hectare by 1980. Although vines were not included in the 1980 inventory, the ground surface on all four plots was covered by an abundance of these species. The most prominent vines were Japanese honeysuckle (*Lonicera japonica* Thunb.), poison ivy (*Rhus radicans* L.), grape (*Vitis* spp.), blackberries (*Rubus* spp.), and greenbriers (*Smilax* spp.).

Table 1.—*Number of understory (≤8.9 cm dbh) trees and shrubs for comparing five stands by species and year of inventory*

| Species | Stand | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1951[1] | 1962[2] | 1980 | 1980[3] | | | |
| | | HE | | UM | LM | MM | HM |
| Trees | *stems/ha* | | | | | | |
| Red oaks *Quercus* L. spp. | 2170 | 5 | 1186 | 951 | 756 | 274 | 1441 |
| White oaks *Quercus* L. spp. | | | 371 | 753 | 479 | 69 | 0 |
| Pine *Pinus* L. spp. | 148 | .... | 673 | 0 | 0 | 0 | 413 |
| Red maple *Acer rubrum* L. | ..... | 0 | 647 | 3583 | 961 | 138 | 3706 |
| Flowering dogwood *Cornus florida* L. | 1198 | 20 | 440 | 4176 | 1715 | 6657 | 274 |
| American holly *Ilex opaca* Ait. | 0 | 0 | 161 | 185 | 205 | 205 | 138 |
| Elm *Ulmus* L. spp. | ..... | 30 | 143 | 544 | 343 | 0 | 138 |
| Sassafras *Sassafras albidum* (Nutt.) Nees | ..... | 0 | 99 | 62 | 413 | 138 | 687 |
| Blackgum *Nyssa sylvatica* Marsh. | 2946 | 0 | 86 | 1260 | 1922 | 2197 | 823 |
| Persimmon *Diospyros virginiana* L. | ..... | 12 | 69 | 12 | 413 | 69 | 0 |
| Red mulberry *Morus rubra* L. | 0 | 0 | 62 | 25 | 0 | 0 | 69 |
| Black cherry *Prunus serotina* Ehrh. | 0 | 0 | 37 | 25 | 0 | 205 | 343 |
| Sweetgum *Liquidambar styraciflua* L. | 1643 | 5 | 30 | 1062 | 687 | 479 | 69 |
| Eastern hophornbeam *Ostrya virginiana* (Mill.) K. Koch | 0 | 0 | 30 | 482 | 0 | 274 | 0 |
| Chinkapin *Castanea pumila* Mill. | 0 | 0 | 25 | 0 | 0 | 0 | 0 |
| Hickory *Carya* Nutt. spp. | 260 | 0 | 7 | 25 | 69 | 0 | 0 |
| Locust *Gleditsia* L. spp. | 0 | 0 | 7 | 0 | 0 | 0 | 0 |
| Ash *Fraxinus* L. spp. | 0 | 0 | 0 | 680 | 0 | 0 | 0 |
| Red bay *Persea borbonia* (L.) Spreng. | 0 | 0 | 0 | 0 | 69 | 0 | 0 |
| Others[4] | 637 | .... | ..... | ..... | ..... | ..... | ..... |
| Shrubs and Small Trees | | | | | | | |
| Huckleberry *Vaccinium* L. spp. | ..... | .... | 2730 | 7129 | 5765 | 4804 | 16131 |
| Shining sumac *Rhus copallina* L. | ..... | .... | 1194 | 0 | 343 | 0 | 274 |
| Yaupon *Ilex vomitoria* Ait. | ..... | .... | 556 | 321 | 0 | 0 | 69 |
| American beautyberry *Callicarpa americana* L. | ..... | .... | 450 | 531 | 343 | 823 | 343 |
| Downy serviceberry *Amelanchier arborea* (Michx. f.) Fern. | ..... | .... | 148 | 0 | 0 | 0 | 0 |
| Hawthorn *Crataegus* L. spp. | ..... | .... | 74 | 544 | 69 | 0 | 205 |
| Devil's-walkingstick *Aralia spinosa* L. | ..... | .... | 74 | 111 | 69 | 69 | 0 |
| Swamp privet *Forestiera acuminata* (Michx.) Poir. | ..... | .... | 7 | 0 | 0 | 0 | 0 |
| Witch-hazel *Hamamelis virginiana* L. | ..... | .... | 0 | 12 | 0 | 0 | 0 |
| Buckthorn *Rhamnus caroliniana* Walt. | ..... | .... | 0 | 0 | 0 | 2814 | 0 |
| Fringetree *Chionanthus virginicus* L. | ..... | .... | 0 | 0 | 0 | 69 | 0 |
| Total | 9002 | 72 | 9306 | 22473 | 14621 | 19284 | 25123 |

[1]Inventory prior to hardwood eradication treatments.
[2]After 11 years of annual hardwood eradication.
[3]Eighteen years after hardwood eradication ended on HE plots.
[4]Not enumerated by species in 1951 but included persimmon, red maple, sassafras, and elm.

## Species Diversity on HE Plots and Comparison Stands

At least 22 species of hardwoods, representing 10 genera,[3] are most commonly associated with southern pines (Hook 1977, Karchesy and Koch 1979). Although HE plots had fewer total stems of these genera in the understory than did the other four stands and none in the overstory (tables 1 and 2), six of the genera were represented in the HE understory while no more than seven were present in the four comparison stands for understory and overstory combined.

With no disturbance, or with increasing time since the last disturbance, the successional trend is for stands to have an increase in number of potential overstory species (Quarterman and Keever 1962). This trend was evident on the five stands discussed. Three of the least disturbed stands (UM, LM and MM) had 9 or more species or species-groups in the overstory compared to 1 on HE plots and 7 in the HM stand (table 2). In contrast, the understory of HE plots was stocked with 17 species or species-groups that have overstory potential compared to 15 or less in the understory of the four comparison stands (table 1).

Understory diversity, based on Simpson's index of dominance (table 3), ranged from 80 percent (MM stand) to 92 percent (LM stand). Since higher values represent greater diversity, there was no stand where any one species was dominant, which indicates the degree of reinvasion by hardwoods on HE plots. Overstory diversity, however, was more variable. On HE plots there was no diversity because pine dominated, and the HM stand had much less diversity (32 percent) compared to the other three stands (UM, LM and MM) with less intensive management.

Table 2.—*Number of overstory (≥9.0 cm dbh) trees and shrubs for comparing five stands by species in 1980*

| Species | Stand | | | | |
|---|---|---|---|---|---|
| | HE | UM | LM | MM | HM |
| | *stems/ha* | | | | |
| Hardwoods | | | | | |
| Red oak | 0 | 25 | 109 | 277 | 30 |
| White oak | 0 | 99 | 74 | 49 | 10 |
| Red maple | 0 | 49 | 5 | 5 | 5 |
| Flowering dogwood | 0 | 25 | 44 | 40 | 15 |
| Elm | 0 | 0 | 5 | 0 | 0 |
| Sassafras | 0 | 25 | 5 | 5 | 0 |
| Blackgum | 0 | 37 | 25 | 114 | 0 |
| Red mulberry | 0 | 0 | 5 | 5 | 0 |
| Sweetgum | 0 | 99 | 64 | 40 | 15 |
| Eastern hophornbeam | 0 | 0 | 5 | 0 | 0 |
| Hickory | 0 | 12 | 10 | 5 | 5 |
| Hawthorn | 0 | 0 | 5 | 0 | 0 |
| Pine | 672 | 111 | 193 | 128 | 198 |
| Total | 672 | 482 | 549 | 668 | 278 |

Table 3.—*Species diversity for comparing five stands based on Simpson's index of dominance*

| Stand | Diversity[1] | |
|---|---|---|
| | Understory | Overstory |
| | *percent* | |
| HE | 90 | 0 |
| UM | 91 | 78 |
| LM | 92 | 68 |
| MM | 80 | 71 |
| HM | 86 | 32 |

[1]Percent diversity $= \left[1 - \sum \left(\frac{n_i}{N}\right)^2\right] 100$

where: $n_i$ = Importance Value for each species in a stand.
N = Total of Importance Values per stand.

## Successional Development by Overstory Components

Basal areas for pine and hardwoods in each stand were separated into overstory and understory components. Overstory basal area (table 4) was then used to categorize the stands into three stages of successional development for comparison (Switzer, Shelton and Nelson 1979). Past management practices have, of course, modified the stands and therefore were important in determining the present stage of overstory development.

The HE and HM stands were in the early stage of development in which pines dominated with more than 80 percent of the total basal area. The LM stand, which had received only minor hardwood control, was in the middle stage of development with about 65 percent of the total basal area in pines. The UM and MM stands, having received no hardwood control, were between the middle and late stages of development with less than 50 percent pine stocking. However, oaks and hickories in the hardwood component of these two stands had not yet reached 60 percent of total basal area required for the late successional stage.

## Similarity of HE Plots to Comparison Stands

Percent similarity between HE plots and comparison stands is given in table 5. For understory species, HE plots were most like the stand with a high level

[3]*Acer, Carya, Celtis, Fraxinus, Liquidambar, Liriodendron, Magnolia, Nyssa, Quercus, Ulmus.*

Table 4.—*Overstory basal area for comparing five stands by species groups*

| Stand | Overstory (≥9 cm dbh) | | | | |
|---|---|---|---|---|---|
| | Basal area | | | Percent of total | |
| | Pine | Hardwood | Total | Pine | Hardwood |
| | ----------$m^2/ha$---------- | | | ---*percent*---- | |
| HE | 21.29 | 0 | 21.29 | 100.0 | 0 |
| UM | 10.89 | 14.88 | 25.77 | 42.3 | 57.7 |
| LM | 14.54 | 7.30 | 21.84 | 66.6 | 33.4 |
| MM | 12.76 | 14.04 | 26.80 | 47.6 | 52.4 |
| HM | 12.56 | 1.21 | 13.77 | 91.2 | 8.8 |

Table 5.—*Similarity of four comparison stands to Hardwood Eradication plots*

| | Stand | | | |
|---|---|---|---|---|
| | UM | LM | MM | HM |
| | ----------*percent similarity*[1]---------- | | | |
| Understory | | | | |
| HE | 44.6 | 47.5 | 29.7 | 54.1 |
| Overstory | | | | |
| HE | 30.9 | 51.7 | 33.3 | 81.8 |

[1]Percent similarity $= \frac{2w}{a+b} \times 100$

where: $w$ = Sum of lower Importance Value for each species being compared between two stands.
$a$ and $b$ = Sums of the species Importance Values in the two stands being compared.

of management (HM). The greatest difference existed between the HE plots and the MM stand, in which there was no hardwood control during management. Hardwood trees had a larger cross-sectional area at 15 cm height in the four comparison stands than on HE plots, and this accounted for much of the difference between stands. The overstory on HE plots was unlike the UM and MM stands but similar to the LM and HM stands, mainly because of the high level of pine stocking in the latter two.

In all but one stand (MM), pine was the predominant overstory species in relative basal area and relative number (table 6). The general trend was for pine importance to decrease with a decrease in management intensity. Overstory oak (climax species) importance in the four comparison stands ranked first (MM) or second (UM, LM, HM), behind pine only. No overstory hardwoods were found on HE plots, but oaks were the second most important species in the understory (table 7). Where hardwood control had been less intensive in the UM, LM and MM stands, understory pines were nonexistent (table 1). In contrast, more intensive hardwood control caused understory pine importance to rank first and fourth in the HE and HM stands respectively (table 7).

## Shade Tolerance

Species intolerant of shade are generally found in the pioneer stage of succession, moderately tolerant species in the second stage, and tolerant species in late succession (Spurr and Barnes 1973). For the two stands where a high level of hardwood control was practiced (HE and HM), 50 percent of the ten predominant understory species (table 7) are classified as intolerant to intermediate. In stands receiving little or no hardwood control (UM, LM and MM), from 70 to 90 percent of the ten predominant understory species are classified as intermediate to tolerant. Tolerance classifications were derived from Harlow and Harrar (1969); Hook (1977); Miller and

Table 6.—*Five predominant overstory species for five stands based on Importance Values*[1]

| Stand and species | Importance Value |
|---|---|
| HE | |
| Pine | 100.0 |
| UM | |
| Pine | 31.0 |
| White oak | 30.7 |
| Sweetgum | 12.6 |
| Red oak | 6.1 |
| Red maple | 5.8 |
| Total | 86.2 |
| LM | |
| Pine | 51.7 |
| Red oak | 17.1 |
| Sweetgum | 9.4 |
| White oak | 9.2 |
| Flowering dogwood | 5.1 |
| Total | 92.5 |
| MM | |
| Red oak | 40.8 |
| Pine | 33.4 |
| Blackgum | 10.6 |
| Sweetgum | 5.1 |
| White oak | 4.8 |
| Total | 94.7 |
| HM | |
| Pine | 81.8 |
| Red oak | 6.9 |
| Flowering dogwood | 3.4 |
| Sweetgum | 3.4 |
| White oak | 2.4 |
| Total | 97.9 |

[1]Importance Value = sum of relative basal area and relative number of each species in a stand; expressed as a percent of stand total.

Jaques (1972); Preston (1965); Putnam, Furnival and McKnight (1960).

Species diversity of overstory trees depends not only on shade tolerance, but also on past management practices that may have favored one species over others, as well as physiological growth rates for individual species. Although site factors can be important determinants of species composition, they were generally uniform in areas where these data were collected.

## SUMMARY AND CONCLUSIONS

Species diversity and basal area of the overstory, percent similarity, and shade tolerance classifications indicated an early stage of successional development for the HE stand when compared to four other stands with varying levels of pine management and hardwood control. Although hardwoods were almost eradicated after 12 years of intensive mechanical and chemical treatments, hardwood reinvasion was only temporarily delayed in this uneven-aged loblolly/shortleaf stand.

Several factors may contribute to the recovery by hardwoods on pine sites after intensive control efforts. Viable seed can be dispersed by wind, animals, water and gravity (Krugman, Stein and Schmitt 1974). Research in the northeastern and southern United States suggests that seeds of numerous hardwood and weed species remain viable after several years of storage in the forest floor (Olmsted and Curtis 1947, Clark and Boyce 1964, Marquis 1975, Wendel 1977, Egley and Chandler 1978). Hardwoods also have an acute propensity to sprout from old rootstock (Merz and Boyce 1956, Reynolds 1956), even after intensive disturbance (Grano 1961). Consequently, rapid recovery of hardwood species is found within many pine stands, even after almost complete eradication. If management by man is excluded from pine sites in the Southeast, and if succession proceeds without disturbance, hardwoods will eventually replace the pines, thus culminating in an oak-hickory climax (Oosting 1956).

Table 7.—*Ten predominant understory species for five stands based on Importance Values*[1]

| Stand and species | Importance Value |
|---|---|
| HE | |
| Pine | 23.7 |
| Red oak | 10.9 |
| Huckleberry | 10.6 |
| Shining sumac | 7.7 |
| Red maple | 5.9 |
| Privet | 4.2 |
| Yaupon | 3.2 |
| Devil's-walkingstick | 3.2 |
| Flowering dogwood | 3.1 |
| American beautyberry | 3.1 |
| Total | 75.6 |
| UM | |
| Eastern hophornbeam | 13.1 |
| Huckleberry | 12.2 |
| Sweetgum | 11.4 |
| Blackgum | 10.5 |
| Elm | 10.2 |
| Flowering dogwood | 9.5 |
| Red maple | 8.2 |
| Ash | 3.3 |
| Devil's-walkingstick | 3.1 |
| White oak | 2.9 |
| Total | 84.4 |
| LM | |
| Huckleberry | 14.8 |
| Blackgum | 12.4 |
| White oak | 8.8 |
| Sweetgum | 8.8 |
| Flowering dogwood | 7.5 |
| Hawthorn | 7.0 |
| Red maple | 6.5 |
| Persimmon | 5.8 |
| Shining sumac | 5.1 |
| Hickory | 5.0 |
| Total | 81.7 |
| MM | |
| Blackgum | 36.3 |
| Flowering dogwood | 19.3 |
| Huckleberry | 12.2 |
| Buckthorn | 8.1 |
| Sweetgum | 5.5 |
| American holly | 3.3 |
| Eastern hophornbeam | 3.2 |
| American beautyberry | 3.0 |
| Black cherry | 1.9 |
| Red oak | 1.8 |
| Total | 94.6 |
| HM | |
| Huckleberry | 23.9 |
| Flowering dogwood | 20.7 |
| Red oak | 12.2 |
| Pine | 11.2 |
| Blackgum | 6.3 |
| Sweetgum | 6.2 |
| Persimmon | 3.8 |
| Shining sumac | 3.6 |
| Sassafras | 2.7 |
| American holly | 2.4 |
| Total | 93.0 |

[1]Importance Value = sum of relative basal area, relative number and relative height of each species in a stand; expressed as a percent of stand total.

## LITERATURE CITED


Cain, M. D., and W. F. Mann, Jr. 1980. Annual brush control increases early growth of loblolly pine. South. J. Appl. For. 4:67–70.

Clason, T. R. 1978. Removal of hardwood vegetation increases growth and yield of a young loblolly pine stand. South. J. Appl. For. 2:96–97.

Clark, F. B., and S. G. Boyce. 1964. Yellow-poplar seed remains viable in the forest litter. J. For. 62:564–567.

Egley, G. H., and J. M. Chandler. 1978. Germination and viability of weed seeds after 2.5 years in a 50-year buried seed study. Weed Sci. 26:230–239.

Fitzgerald, C. H., F. A. Peevy, and D. E. Fender. 1973. Rehabilitation of forest land: the Southern Region. J. For. 71:148–153.

Grano, C. X. 1961. Hardwood reoccupation of bulldozed sites, p. 7-8. *In* Hardwood sprout development on cleared sites. U.S. Dep. Agric. For. Serv. Occas. Pap. 186, South. For. Exp. Stn., New Orleans, La.

Grano, C. X. 1970. Small hardwoods reduce growth of pine overstory. U.S. Dep. Agric. For. Serv. Res. Pap. SO-55, 9 p. South. For. Exp. Stn., New Orleans, La.

Harlow, W. M., and E. S. Harrar. 1969. Textbook of dendrology. 5th ed. 512 p. McGraw-Hill Book Co., New York.

Hook, D. D. 1977. Eco-physiology of hardwood species associated with southern pines—a review. Clemson Univ. Dep. For. Tech. Pap. 6, 17 p. Clemson, S.C.

Karchesy, J., and P. Koch. 1979. Energy production from hardwoods growing on southern pine sites. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. SO-24, 59 p. South. For. Exp. Stn., New Orleans, La.

Krugman, S. L., W. I. Stein, and D. M. Schmitt. 1974. Seed biology, p. 5–40. *In* Seeds of woody plants in the United States. U.S. Dep. Agric. For. Serv. Agric. Handb. 450.

Little, E. L., Jr. 1979. Checklist of United States trees (native and naturalized). U.S. Dep. Agric. For. Serv. Agric. Handb. 541. 375 p.

Marquis, D. A. 1975. Seed storage and germination under northern hardwood forests. Can. J. For. Res. 5:478–484.

Merz, R. W., and S. G. Boyce. 1956. Age of oak "seedlings". J. For. 54:774–775.

Miller, H. A., and H. E. Jaques. 1972. How to know the trees. 2nd ed. 302 p. William C. Brown Co., Dubuque, Iowa.

Monk, C. D. 1967. Tree species diversity in the eastern deciduous forest with particular reference to North Central Florida. Am. Nat. 101:173–187.

Murphy, P. A., and R. M. Farrar. 1981. A test of the exponential distribution for stand structure definition in uneven-aged loblolly-shortleaf pine stands. U.S. Dep. Agric. For. Serv. Res. Pap. SO-164, 4 p. South. For. Exp. Stn., New Orleans, La.

Odum, E. P. 1975. Ecology: the link between the natural and social sciences. 2nd ed. 244 p. Holt, Rinehart and Winston, New York.

Olmsted, N. W., and J. D. Curtis. 1947. Seed of the forest floor. Ecology 28:49–52.

Oosting, H. J. 1956. The study of plant communities. 2nd ed. 440 p. W. H. Freeman and Co., San Francisco, Ca.

Popovich, L. 1980. Monoculture, a bugaboo revisited. J. For. 78:487–489.

Preston, R. J., Jr. 1965. North American trees. 2nd ed. 395 p. Iowa State Univ. Press, Ames, Iowa.

Putnam, J. A., G. M. Furnival, and J. S. McKnight. 1960. Management and inventory of southern hardwoods. U.S. Dep. Agric. For. Serv. Agric. Handb. 181. 102 p.

Quarterman, E., and C. Keever. 1962. Southern mixed hardwood forest: climax in the Southeastern Coastal Plain, U.S.A. Ecol. Monogr. 32:167–185.

Reynolds, R. R. 1956. Upland hardwoods in south Arkansas pine stands—aerial or underground fifth column? J. For. 54:585–586.

Reynolds, R. R. 1959. Eighteen years of selection timber management on the Crossett Experimental Forest. U.S. Dep. Agric. Tech. Bull. 1206. 68 p.

Spurr, S. H., and B. V. Barnes. 1973. Forest ecology. 2nd ed. 571 p. The Ronald Press Co., New York.

Switzer, G. L., M. G. Shelton, and L. E. Nelson. 1979. Successional development of the forest floor and soil surface on upland sites of the East Gulf Coastal Plain. Ecology 60:1162–1171.

Walstad, J. D. 1976. Weed control for better southern pine management. Weyerhaeuser For. Pap. 15, 44p. Weyerhaeuser Co., Hot Springs, Ark.

Wendel, G. W. 1977. Longevity of black cherry, wild grape, and sassafras seed in the forest floor. U.S. For. Serv. Res. Pap. NE-375, 6 p. Northeast. For. Exp. Stn., Upper Darby, Pa.

## CONVERSION TO ENGLISH UNITS

| | |
|---|---|
| Inches | = Centimeters × 0.3937 |
| Feet | = Meters × 3.281 |
| Pounds | = Kilograms × 2.205 |
| Gallons | = Liters × 0.2642 |
| Cubic Feet | = Cubic meters × 35.31 |
| Cubic feet per acre | = Cubic meters per hectare × 14.29 |
| Acres | = Hectares × 2.471 |
| Stems per acre | = Stems per hectare × 0.4047 |

CAIN, MICHAEL D., and DANIEL A. YAUSSY.
1983. Reinvasion of hardwoods following eradication in an uneven-aged pine stand. U.S. Dep. Agric. For. Serv. Res. Pap. SO-188, 8p. South. For. Exp. Stn., New Orleans, La.

Study quantitatively describes the woody plant component that developed in an uneven-aged loblolly/shortleaf pine stand following hardwood eradication. Comparisons are made with four other stands managed at various intensity levels.

**Additional keywords:** *Pinus echinata; Pinus taeda;* competing vegetation; natural plant succession; selection management; tolerance.

☆U.S. GOVERNMENT PRINTING OFFICE: 1983- 669-085/30