RESEARCH REPORT

# A Restoration Success: Longleaf Pine Seedlings Established in a Fire-Suppressed, Old-Growth Stand

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Burning coupled with hardwood tree removal shows promise for restoring old-growth longleaf pine in Alabama natural area.

Prior to European settlement, forested savannas dominated by longleaf pine and the most diverse herbaceous layer in temperate North America blanketed an estimated 90 million acres (37 million ha) of the southeastern United States. These forests, termed savannas for their open, park-like nature, were swept by fire once every one to ten years (Mattoon 1922, Chapman 1932, Christensen 1981). Due to fire suppression, agriculture and site conversion, longleaf forests now exist on less than 3 percent of their former range (Frost 1993). A 1995 U.S. Biological Survey Report listed the longleaf pine forest as the third most endangered ecosystem in the United States (Noss and others 1995). Old-growth longleaf pine forests exist in an even more imperiled state, covering less than 9,900 acres (4,000 ha), or 0.01 percent of their former extent (Means 1995). Recent harvests of the remaining old-growth acreage make the ecological restoration of old-growth longleaf pine forests extremely urgent.

Private, state, and federal land managers have recently undertaken ecological restoration of the longleaf pine forests in the southeastern United States. Restoration to this point has lacked information on reducing litter accumulations, herbaceous species establishment, changes in overstory structure, and the fate of longleaf pine regeneration during the restoration process.

One area where the impacts of ecological restoration on longleaf pine forests are being studied is the Flomaton Natural Area (FNA), which is currently owned by International Paper (Meldahl and others 1994, Wade and others 1998). The Society of American Foresters recognized the importance of this stand in 1963 when they designated the area as the E. A. Hauss Old-Growth Longleaf Natural Area (Walker 1963).

The FNA is a 60-acre (25-ha) virgin longleaf pine stand that underwent more than 45 years of fire suppression. In 1995, we began a major restoration project with the reintroduction of fire (Kush and Meldahl 1996). Since then, we have been monitoring and managing the FNA as an old-growth longleaf pine habitat. The stand was burned again in 1996, 1997, and 2001. A fuel-wood operation was also conducted in 1996, in which all hardwood trees were mechanically removed. Two of us (Kush and Meldahl 2000) reported on the composition of the stand before restoration efforts. At the start of

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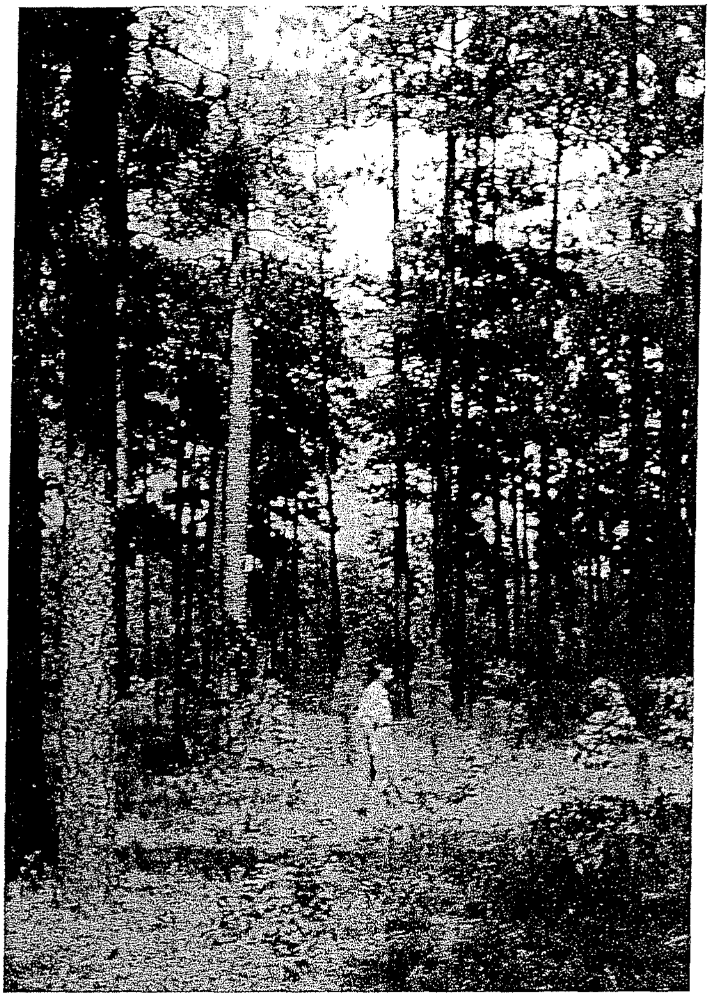

Figure 1a. 1958. Flomaton Natural Area, a 60-acre remnant longleaf pine stand in southern Alabama, was left unburned until 1995.

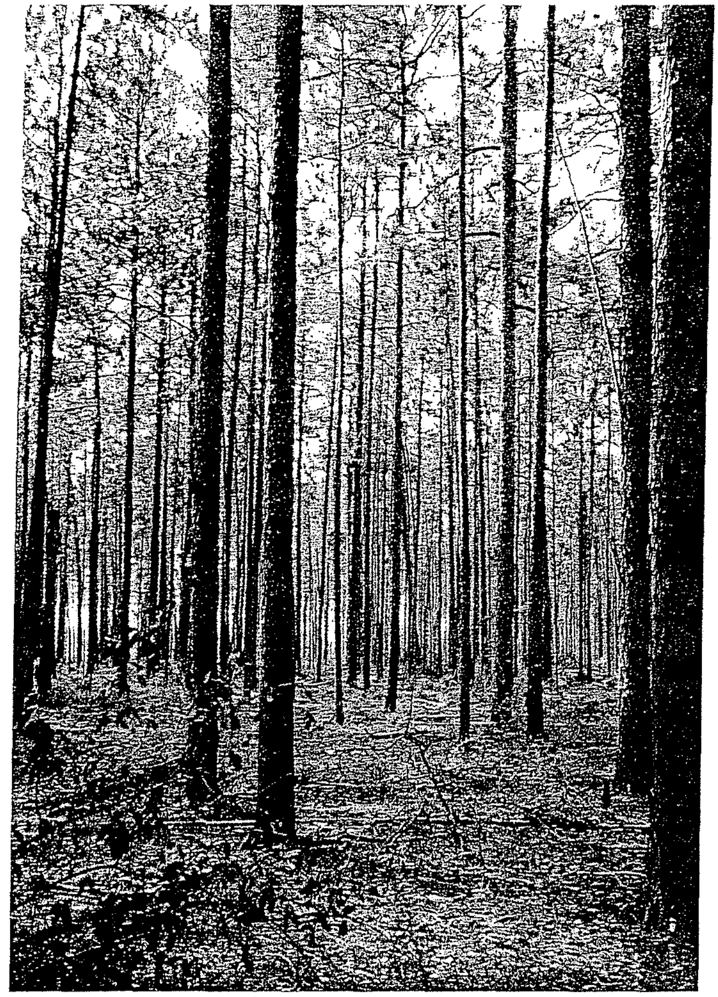

Figure 1b. 1997. Same portion of Flomaton Natural Area, two years after a prescribed burning protocol was begun and one year after the removal of all hardwoods. Co-author John Kush recalls visiting the area at that time and being pleased by the results of the restoration effort. *All photos courtesy of John Kush*

the restoration project, we found no longleaf pine seedlings less than 0.78 inches (2 cm) diameter at breast height (DBH). Varner and colleagues (2000) described changes in litter depth, soil composition, and the overstory. At that time, we reported the loss of all longleaf pine less than 3.0 inches (7.5 cm) DBH because of restoration efforts (Figures 1a and 1b).

A large longleaf pine seed crop occurred at the FNA in autumn 1996. We observed thousands of seedlings per hectare in the stand in 1997. In an effort to determine if longleaf pine regeneration was going to survive restoration efforts, we conducted annual surveys as described in an earlier article (Kush and Meldahl 2000). Beginning in 2001 and continuing in 2002, more intensive studies were conducted to describe the status of longleaf pine regeneration in the FNA.

# Methods

## *Description of the Study Area*

The FNA is located in Escambia County, southern Alabama, at 207 feet (63 m) above mean sea level. The climate is humid and mild with a mean annual precipitation of 61.4 inches (156 cm) well distributed throughout the year. The warmest months are July and August with average daily maximum and minimum temperatures of 91°F and 68°F (33°C and 20°C), respectively. The coldest months are December and January with average daily temperatures of 64°F and 37°F (18°C and 3°C), respectively. The predominant soil series is the Orangeburg. Formed in marine sediments of sandy loams and sandy clay loams, these soils are low in natural fertility and organic matter.

## *Inventory Procedures*

Prior to the onset of restoration efforts, we established 30 permanent 0.2-acre (0.08-ha) plots to monitor the overstory on a 60-m x 80-m grid located at least 30 meters from the edge of the stand (see Kush and Meldahl 2000). Four 1.42-$m^2$ quadrats per plot, located on the cardinal directions 3 meters from plot center, have been surveyed annually for longleaf pine seedlings. On a subset of plots, we randomly selected ten codominant and dominant trees for use in an annual survey of longleaf pine cone crops. This survey followed the guidelines established by Croker and Boyer (1975).

In 2001, we established a separate study of gaps within the FNA to determine the status of regeneration within these areas. Several gaps were identified on a stem map of the longleaf pine within the FNA. Gaps well away from any edge effect or disturbed areas from the fuel-wood operation were assigned a number and five of these gaps were randomly selected for study. Once a gap was selected, the length, width, and orientation were recorded. Four transects per gap, extending from 1.8 meters from the gap center to a point at least 4 meters beyond the gap edge were established in each gap. Every 3 meters, a chaining pin was placed for their future relocation. These transects were installed along the long axis of the gap and its right angle. Transects are 50 centimeters wide and seedlings have been mapped on an X-Y basis. In addition, we measured and recorded the ground line diameter (GLD) and height for every fifth seedling.

In 2002, we conducted a more extensive survey for seedlings on the established plots in the FNA. Transects 30 meters in length and 45 centimeters wide have been laid out on the north-south and east-west axes across each of the 30 overstory plot centers. We again mapped the seedlings on an X-Y basis in order to monitor them in the future.

Table 1. Results from the annual survey of overstory plot quadrats for longleaf pine seedlings at the Flomaton Natural Area.

| Year | Seedlings/ha | Range | Standard error of the mean |
|---|---|---|---|
| 1997 | 103,481 | 0-256,344 | 11,716 |
| 1998 | 42,189 | 0-99,180 | 7,245 |
| 1999 | 69,328 | 0-145,734 | 10,666 |
| 2000 | 34,691 | 0-87,456 | 5,011 |
| 2001 | 13,065 | 0-45,333 | 2,019 |
| 2002 | 7,678 | 0-56,667 | 1,968 |

Table 2. Results from the annual survey of a subset of overstory longleaf pine for cone counts at the Flomaton Natural Area.

| Year | Percent Stocking | Cones/Tree |
|---|---|---|
| 1997 | 83.0 | 35.0 |
| 1998 | 46.1 | 102.3 |
| 1999 | 78.4 | 45.2 |
| 2000 | 58.8 | 37.2 |
| 2001 | 43.3 | 39.7 |
| 2002 | 43.3 | 29.8 |

## Results

Table 1 presents our findings from the annual surveys for longleaf pine seedlings and counts of cones in the FNA. In 1997, following the large longleaf pine seed crop of 1996, there were 41,878 seedlings per acre (103,481 seedlings per hectare) with 83 percent stocking of the quadrats (stocking was defined as the presence of at least one seedling within a quadrat). The percent stocking and density have gradually declined. There was a slight increase in density and stocking in 1999 due to the relatively large longleaf pine seed crop in 1998. In 2000, we had the entire stand bush-hogged to reduce competition that had developed because unseasonably dry weather from 1998 to 2000 kept us from burning the stand. The bush-hogging operation was carried out to minimize the impact on the longleaf pine regeneration, and there was no noticeable loss in seedling density.

The more intensive survey we conducted in spring 2002 produced very similar results to our survey of quadrats in 2001. The number of seedlings dropped to an average 3,107 seedlings per acre (7,678 seedlings per hectare). Twenty-nine of the 30 plots had seedlings, including plots with basal areas greater than 130 ft$^2$ per acre (30 m$^2$ per hectare). We also measured litter depth because it can affect germination success and found that litter depth averaged 4.8 inches (12.2 cm) with a range of 3.0 to 7.1 inches (7.6 to 18.1 cm).

These results indicate that the number of seedlings has not been limited by poor or inadequate cone production. Wahlenberg (1946) reported good longleaf pine seed crops occur at five- to seven-year intervals. Every year since the start of the restoration efforts at the FNA has been a "good" cone production year (Table 2), according to work by Croker and Boyer (1975), who reported that each tree would have 35 cones in fair-to-good seed years.

Stand basal area does not appear to be affecting cone production. Croker (1973) found that cone production declined with increasing stand basal area in excess of 30 ft$^2$ per acre (7.1 m$^2$ per hectare). The stand basal area for the FNA is 74 ft$^2$ per acre (17 m$^2$ per hectare). There was no correlation between plot basal area and the cones produced per tree.

Longleaf pine seed requires contact with mineral soil for satisfactory germination and establishment (Boyer 1993). Croker and Boyer (1975) reported a burn one year before seedfall would provide an adequate seedbed. Forty-five years of fire suppression at the FNA left a thick litter layer that averaged 6.2 inches (15.8 cm) at the base of each tree (Kush and Meldahl 2000). Even after three prescribed fires, the litter layer still averaged 4.5 inches (11.4 cm) across the stand (Varner and others 2000). Despite the litter depth, seedlings are becoming established at the FNA. The reason for this apparent success may be due to the low intensity fires that have been used to avoid the entire consumption of the litter layer.

Canopy gaps are the most likely areas for the establishment of longleaf pine seedlings due at least in part to the shade intolerance of longleaf pine combined with higher light levels within these gaps. Light, litter depth, and nutrient and water availability within the gap are all factors in the successful regeneration of longleaf pine (Brockway and Outcalt 1998). Results from

Table 3. Longleaf pine seedling data collected in 2001 from five gaps located in the Flomaton Natural Area.

| Gap | Gap size (ha) | Seedlings/ha | Standard error of the mean |
|---|---|---|---|
| 1 | 0.06 | 4,669 | 1,334 |
| 2 | 0.05 | 1,717 | 660 |
| 3 | 0.10 | 34,888 | 6,841 |
| 4 | 0.09 | 19,084 | 3,895 |
| 5 | 0.16 | 47,991 | 7,058 |
| Average | 0.09 | 21,670 | |
| **Gap** | **Gap size (ha)** | **GLD[a] (cm)** | **Height[b] (cm)** |
| 1 | 0.06 | 1.26 | 5.08 |
| 2 | 0.05 | 0.00 | 0.00 |
| 3 | 0.10 | 1.36 | 4.84 |
| 4 | 0.09 | 0.88 | 26.67 |
| 5 | 0.16 | 1.42 | 5.77 |

[a]ground-line diameter for all seedlings
[b]only those seedlings that have initiated height growth

a survey of five gaps are presented in Table 3. Across all gaps there was an average of 8,770 seedlings per acre (21,670 seedlings per hectare). In four of the five gaps, a few seedlings had initiated height growth from the grass-stage. Longleaf pine is noted for its juvenile growth form, which is known as the "grass-stage." In the grass-stage, longleaf concentrates its first few years' growth on root development and makes little above ground growth. During this stage, the seedling is extremely resistant to fire. Many seedlings have a GLD greater than 0.39 inches (1 cm), which Boyer (1993) reported is needed for a seedling to be relatively safe from mortality in carefully prescribed and executed winter fires.

# Discussion

## Concerns with Fire

We have encountered several problems at the FNA in trying to restore fire to this longleaf pine ecosystem.

1. *Draped fuel* was one of the major concerns with the return of fire to the stand after more than 40 years of fire suppression. Draped fuels are needles, leaves, twigs, and so forth that have fallen from above and have lodged on lower branches and brush. These are aerial fuels that can facilitate the movement of fire into tree crowns. These fuel conditions necessitate cool fires.
2. *Slow movement of the fire through the dense stand* resulted in spotty burning in the stand and the buildup of heat around the base of larger, older trees.
3. *Residence time of heat around the bases of the large, older trees.* At the onset of restoration efforts at FNA, pine needle litter depths at the bases of trees were substantial and potentially lethal. The aspect of danger associated with pine litter occurs when 1) heavy amounts accumulate under large trees and 2) feeder roots invade this rich organic layer. The lethal nature of fire occurs when it kills a large portion of these feeder roots or when the litter around the base of the tree burns, girdling the tree. For example, in 1993, a trash fire escaped and burned through an adjacent portion of the stand. Due to the heavy litter accumulations in this unburned portion, the largest trees were girdled at their bases from the heat generated by the burning litter. One of the major concerns with any restoration effort needs to be the avoidance of a rapid reduction of the accumulated litter layer.

   Each of the fires in FNA has required extensive mop-up due to the heat buildup in the organic layer around the bases of these trees. Although the fire had extinguished several hours earlier and there were no signs of smoke, enough heat had built up in the organic litter layer to burn crew members' hands hours later. Crew members carried water bags for hours and, at times, a day after the fire was "extinguished." Water from these bags was applied to tree bases until the surrounding area was thoroughly soaked.
4. *Snags continuing to burn* have been a threat in each successive fire in Flomaton. While retention of snags is important, the liability to the stand is much more critical. Snags ignite and then burn for hours or days after the fire has extinguished. When the entire snag or large branches fall to the forest floor, they can reignite the litter layers. This type of fire can go unnoticed for days and destroy the remnant stand.

## Alternatives

Potential alternatives/supplements to fire that should be considered in the restoration of old-growth longleaf pine stands include the following.

1. *Mechanical removal of hardwoods.* Once hardwoods reach 3-4 inches (7.6-10.2 cm) DBH, they will be little affected by the cooler burns that should be used for the first few fires in old-growth stands. We realized early on that fire alone would never remove all of the hardwoods. As a result, we implemented a fuel-wood operation in the Flomaton Natural Area due to the size and density of hardwoods.
2. *Use of herbicides.* If the overstory is too sparse to provide enough fuel to burn, a one-time application of herbicide may be enough to reduce the hardwood competition, provide fuel for a burn, or release natural or planted seedlings.

# Guidelines for Restoring Fire-Suppressed Stands

## Protect Pine Overstory

Any restoration effort must emphasize the retention of the overstory and the valuable needle litter it provides as fuel. Pine needle litter carries fire to kill hardwoods, encourages herbaceous plant establishment, and exposes soil for longleaf pine seedling germination. If hardwoods are harvested, operators must be supervised carefully to avoid causing damage, such as basal wounds to trees and soil compaction, to the residual stand. During and after prescribed fires, water must be applied to bases of residual trees. If we fail to follow any of these recommendations, we open stands to hardwood sprouting, spread of invasive species, and invite costly corrective measures. *The fact is, without longleaf pine, you can have no longleaf pine ecosystem.*

## Evaluate Hardwoods Early

Hardwood litter deters fire, longleaf seedling germination, and herbaceous plant establishment. Carefully harvesting all stems that will not be killed by fire can accelerate restoration of the residual stand. However, if longleaf pine basal area is too low, vigorous hardwood sprouting may negate any harvest impacts. Evaluation of the composition and structure of hardwoods can forestall problems in stand restoration.

## Manage Canopy Gaps and Use Seed Crops

Successful regeneration in gaps and maintaining a diversity of age and size classes can serve as insurance against hardwood and non-native invasions. For example, if a gap is colonized by nearby hardwood or non-native remnants, then this area will have to be harvested. This harvest would have to wait until a seed crop was available or seedlings planted. Either of these alternatives will require time, effort, and expense.

## Use Fire Carefully

Fires in fire-suppressed stands can be extremely dangerous and counterproductive. First, opting for a series of cool, winter burns can accomplish most of the goals that one might expect to accomplish by using summer fires. Only after litter layers are under control do managers need to apply spring and summer fires. Second, reliance upon anyone other than an experienced fire manager is dangerous. Finally, as has been emphasized, mop-up with generous amounts of water is critical.

## Watch Non-Natives

Non-native species (kudzu, privet, Chinese tallow, mimosa, and others) can quickly invade and alter the disturbed sites that are often created during restoration activities. Overlooking or downplaying their presence will be expensive and time consuming.

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