# SLASH PINE REGENERATION AND GROUNDCOVER RESPONSES FOLLOWING HARVESTING IN HYDRIC FLATWOODS

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**Abstract**—As part of a long term project assessing different strategies for converting slash pine (*Pinus elliottii*) plantations to uneven-aged, multifunctional forests, we evaluated the effects of five different harvest methods (group selection, shelterwood, third row thin, 'cut 2 leave 3' row thin, and staggered third row thin) on natural regeneration of slash pine and groundcover one growing season following harvesting. While shelterwood and group selection harvests resulted in highest total number of slash pine seedlings of any size (9708 and 9132 seedlings/ha), group selection and 'cut 2 leave 3' row thinning had the highest number of large sized seedlings (408 and 340 seedlings greater than 60 cm). Quick height growth of slash pine regeneration will be a critical component of the stand conversion process, particularly where prescribed fire may be used for vegetation control. Although, the harvest treatments resulted in considerable decreases in shrub cover as a result of the mechanical operations, the shrub component still dominated ground cover in all of the treatments after one growing season. Shelterwood treatment had the least shrubs (approximately 12 percent) and had the highest proportion of graminoids (approximately 25 percent of total groundcover) compared to other harvest treatments. Total species richness varied from 21 genera in uncut control to 40 genera in staggered third row thin treatment. The most appropriate harvesting regime for converting plantations may be dependent on prioritizing objectives for restoring both forest structure in addition to groundcover diversity.

## INTRODUCTION

In the last few decades, concerted efforts have been made to restore southern pine ecosystems throughout the southeast, particularly in context to promoting biodiversity within longleaf pine (*Pinus palustris*) ecosystems. Across the landscape, the natural, pre European settlement, longleaf pine ecosystems were typically variable in density, tree sizes and age classes (Pederson and others 2008, Platt and Rathbun 1993). This natural structural variability, along with a frequent regime of low intensity fires sparked by lightening, were key components that made this particular ecosystem rich in plant and wildlife diversity. Interestingly, natural characteristics of slash pine (*Pinus elliottii*) dominated ecosystems are similar to longleaf pine ecosystems in diversity, structure, and function (Doren and others 1993); and in fact, in wetter hydric ecosystems, longleaf pine may occur only as a co dominant or even subordinate species to slash pine.

As of 2007, slash pine including mixed stands with longleaf pine forests covered 5.3 million hectares (Smith and others 2009), with about 79 percent of the total area concentrated in Florida and Georgia (Barnett and Sheffield 2005); however most of that acreage was in plantation management. Interest in restoring and managing more structurally complex flatwoods with a component of slash pine in addition to longleaf pine has increased recently, yet less is currently known about appropriate management of slash pine forests or natural slash pine regeneration dynamics than longleaf pine. Two-aged and uneven-aged silvicultural methods have been proposed as techniques for restoring and maintaining these ecosystems. A basal area approaching 4 to 5 $m^2$/ha, as would be used with the irregular shelterwood method (Dickens and others 2004, Langdon and Bennett 1976) or up to 11.5 $m^2$/ha, typical of single and group selection methods, have been suggest to promote early seedling establishment or growth of slash pine (McMinn 1981). Complicating the matter, slash pine seedlings are not tolerant of fire, though saplings become more resistant as they mature, grow in tree height, and the bark thickens (Doren and others 1993). Thus, a main question for land managers remains regarding the feasibility of uneven-aged slash pine management and restoration of groundcover in areas where prescribed fire is intended for fuels reduction.

An operational scale project was designed to investigate the long term strategies for converting slash pine plantations to more 'natural' uneven-aged ecosystems. The overall objectives of that project are to determine the harvesting strategies that lead to sustainable uneven-aged forests in terms of forest structure, timber production and other ecological

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Citation for proceedings: Schweitzer, Callie J.; Clatterbuck, Wayne K.; Oswalt, Christopher M., eds. 2016. Proceedings of the 18th biennial southern silvicultural research conference. e–Gen. Tech. Rep. SRS–212. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 614 p.

services such as ground cover diversity and carbon sequestration. The initial conversion harvesting treatments ranged from traditional thinning operations to uneven-aged methods. One growing season after harvesting, slash pine regeneration and groundcover responses were measured in order to quantify and compare tree regeneration densities and sizes and groundcover response within and between 5 conversion harvesting treatments in slash pine plantations.

## METHODS

Conversion harvesting treatments were installed in mature slash pine plantations at Tate's Hell State Forest, Florida, in 2009. Tate's Hell State Forest (29.83N, 84.79W) consists of about 820 km$^2$ of poorly drained lowland mesic hydric flatwoods site between the Apalachicola and Ochlockonee Rivers in the panhandle Florida. The climate is humid subtropical with annual precipitation totaling about 147 cm, of which about 49 percent is received during June to September. Although more than 40 unique soil types occur within the forest, four groups account for the majority of the soils, namely, (a) Scranton Rutlege, (b) Plummer Surrency Pelham, (c) Meadowbrook Tooles Harbeson, and (d) Pamlico Pickney Maurepas. All are poorly drained hydric soils. The site was once a swampy mosaic of wet prairies, cypress (*Taxodium* spp.) sloughs, Atlantic White Cedar (*Chamaecyparis thyoides*) forests and other wetland and pine flatwoods communities, but large scale silvicultural operations and hydrological manipulations during 1960s through 1980s converted extensive areas of native habitats to slash pine plantation. Stands were established following intensive mechanical site preparation, bedding and planting at high densities.

Five conversion harvest treatments were completed in December 2011 in 30 yr old slash pine plantations with initial basal area 30 m$^2$/ha and a QMD of 18 cm. Treatments consisted of three intensities of thinning (3rd row thinning, "take 2 rows, leave 3" thinning, and "stutterstep across rows"), irregular shelterwood method to a residual basal area of 9 m$^2$/ha , and group selection method in which gap openings of 0.10, 0.20, 0.40 and 0.08 ha sizes were created, with the remaining matrix third row thinned. Each harvest treatment was 6 ha in size and was replicated across 3 unique, noncontiguous blocks across the forest.

Each of the harvest treatment plots had five permanent measurement plots of 25m x 25m, which were located at random grid points within each treatment plot. Within each 25m x 25m measurement plot, we established two 5m x 5m tree regeneration plots at diagonally opposite corners (south east and north west corners) and a 15m line transect oriented north to south from which to estimate understory and groundcover species (fig. 1).

Densities of tree seedlings < 1.4m in height were recorded on each of the ten regeneration plots located within the permanent measurement plots described above as well as on an additional ten 5m x 5m regeneration plots randomly established outside the permanent measurement plots to account for a more detailed response. Other attributes of the regeneration plots including their position within the harvest treatment (e.g. thinned vs. unthinned area, gap vs. matrix), vegetation condition (clear vs. shrubby) and litter status were also noted. Each recorded seedling was sorted by height/size category (<30cm, 30 to 60cm,

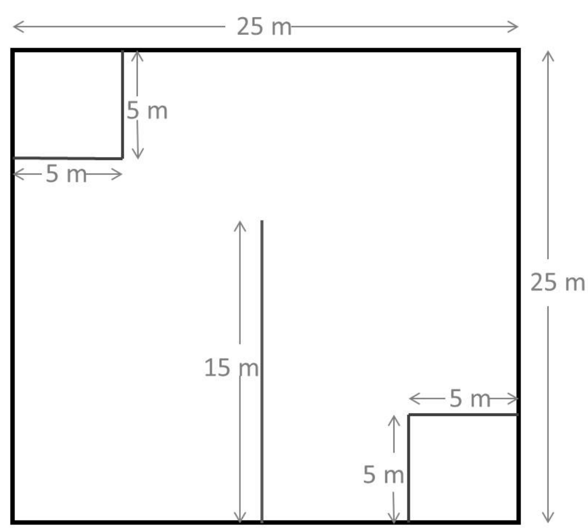


Figure 1—Layout of a 25m x 25m measurement plot with two 5m x 5m regeneration plots at SE and NW corners and a 15m line transect used to sample natural regeneration and groundcover.

>60cm). Analyses of variance were carried out to test the effects of harvest treatments on seedling densities. Tukey's HSD (Honestly Significant Differences) test was performed at $\alpha = 0.05$ to test for significant differences.

Groundcover, including forbs/herbs, graminoids (grasses, sedges, and rushes), and shrubs and vines, were sampled along 15m line transects. We also included small tree seedlings along 15m line transect in our assessment of groundcover. Using the line intercept method, vertically projected foliar cover was recorded for each plant species along transect. These data were then transformed into mean percent cover values for each of the harvest treatments. The groundcover assessment was carried out during September to October 2012 when the groundcover species were in a phenological stage most suitable for identification. Tree regeneration responses to the harvest treatments were assessed in April 2013 after one year of harvesting and before the beginning of next growing season.

## RESULTS AND DISCUSSION

### Tree Regeneration

Seedlings of slash pine were observed in all of the harvested treatment plots and were significantly higher in number than on the uncut control plots (table 1). The maximum numbers of total seedlings (all heights combined) were observed in the shelterwood (9708 seedlings/ha) and group selection (9132 seedlings/ha) treatments (table 1), although these were not were not significantly different from other treatments. In comparison, the uncut control plots averaged 412 seedlings/ha. The majority of seedlings recorded in the uncut control were in a single plot which had been accidentally burnt prior to installation of this project, which led to creation of small gaps where the regeneration occurred.

The size of regeneration is also of importance because the large sized seedlings may be more likely to survive prescribed burns. Group selection and 'cut 2 leave 3' row thin treatments had the highest number of the large sized seedlings > 60 cm (408 and 340 seedlings/ha respectively), though none of the treatments were significantly different due to the high variability in densities of this size class (table 1). It is likely that the largest seedlings were actually advance regeneration released by the increased light in the open areas of these two treatments. The shelterwood treatment, which had resulted in the highest total number of seedlings, actually had the least number of seedlings > 60 cm (80 seedlings/ha). Plots in the shelterwood treatment were the most affected by harvest operations in terms of disturbance to soil structure due to the extensive movement of harvest equipment across the stands. It is possible that despite abundant seedling emergence in shelterwood treatment, a large proportion of seedlings could not establish and reach larger sizes under these disturbed soil conditions.

We also more specifically compared regeneration within thinned or harvested areas and unthinned rows (table 2). Within the 'cut 2 leave 3' row thin treatment, natural regeneration in the thinned portion where rows were cut out was considerably higher than in the areas of unthinned rows (9936 total seedlings/ha vs 3952 seedlings/ha respectively). Interestingly though, in the group selection treatments, the total number of seedlings were higher in the thinned matrix portion (11388 seedlings/ha) than in the gap portion (6000 seedlings/ha), though most of the seedlings in the

**Table 1—Estimates of regeneration (mean + / - one standard deviation of number of seedlings) in mature slash pine stands one year following different harvest treatments at Tate's Hell State Forest, FL**

| Harvest Treatment | Density (seedlings/ha) by height class: | | | |
|---|---|---|---|---|
| | <30cm | 30 to 60cm | >60cm | Total seedlings |
| 3rd Row Thin | $5180 \pm 2424^{b}$ | $2160 \pm 656^{b}$ | $260 \pm 132^{a}$ | $7600 \pm 2700^{b}$ |
| Cut 2 Leave 3 Row Thin | $4332 \pm 548^{b}$ | $1980 \pm 4.95^{b}$ | $340 \pm 120^{a}$ | $6620 \pm 668^{b}$ |
| Group Selection | $6000.15 \pm 4136^{b}$ | $2668 \pm 1472^{b}$ | $408 \pm 232^{a}$ | $9132 \pm 5460^{b}$ |
| Shelterwood | $6420 \pm 3148^{b}$ | $3208 \pm 2244^{b}$ | $80 \pm 52^{a}$ | $9708 \pm 5232^{b}$ |
| Staggered 3rd Row Thin | $5292 \pm 2632^{b}$ | $2892 \pm 1368^{b}$ | $128 \pm 24^{a}$ | $8312 \pm 3736^{b}$ |
| Uncut Control | $172 \pm 120^{a}$ | $60 \pm 68^{a}$ | $180 \pm 312^{a}$ | $412 \pm 492^{a}$ |

**Table 2—Estimates of regeneration (mean number of seedlings per hectare) observed in cut and uncut portions within the harvest treatment in mature slash pine stands after one year following different harvest treatments at Tate's Hell State Forest, FL**

| Harvest Treatment | Density (seedlings/ha) by height class: | | | |
|---|---|---|---|---|
| | <30cm | 30 to 60cm | >60cm | Total seedlings |
| Cut 2 Leave 3 Row Thin | | | | |
| Within Thinned Stand Area | 6272 | 3232 | 432 | 9936 |
| Within Unthinned Stand Area | 2600 | 900 | 452 | 3952 |
| Group Selection | | | | |
| Within Gap | 2452 | 2680 | 868 | 6000 |
| Within Matrix | 8532 | 2732 | 124 | 11388 |

matrix portion were in the smallest size class while the gap portion had a substantially higher number of large sized seedlings (table 2). Similar observation were made in longleaf pine forests by McGuire and others (2001) and Gagnon and others (2004) where higher survival and density of longleaf pine seedlings after one growing season was observed in matrix portion than in the gaps. In these and other studies (Palik and others 1997), the seedlings also grew to a larger size in the gaps than in the matrix portion. Additionally, the greater abundance of small seedlings in the matrix portion in our study may also be due to the proximity to greater number of seed trees. However, there was no definite spatial pattern found between the seedling density in the gaps and the distance from the gap border. These initial observations suggest a harvest treatment that combines gap openings from a group selection treatment with a 'cut 2 leave 3' row thin treatment in the matrix of the stand may be among the best treatments to obtain natural regeneration across the entire treatment area.

Though not quantified, an ocular observation of regeneration response across all the treatments suggested that the regeneration hot spots had three common attributes. These spots represented areas or patches in the stands which were (1) free of shrubs and excessive hydric conditions, (2) had sufficient illumination, and (3) did not have more than 15cm thick litter layer.

## Groundcover Response

After a period of about one growing season following harvesting, all of the treatment plots had decreased amounts of total percent groundcover as compared to the uncut control (fig. 2). This initial effect was mainly due to the fact that the harvesting operations had decimated a considerable amount of shrubs that existed prior to harvesting. Shrub cover in the uncut control was 44 percent compared to 18 to 26 percent in the harvested plots. Shrubs also represented 98 percent of the relative cover of all plant functional groups in the uncut controls, but only 66 to 88 percent of relative cover in the harvested treatment plots. The shelterwood treatment, which involved the most intensive harvesting, had the least amount of total groundcover (approximately 17 percent) primarily due to the reduction in the shrub layer.

The shelterwood treatment despite resulting in the least groundcover had the highest absolute as well as relative proportion of graminoid cover (approximately 25 percent of total groundcover) of all harvesting treatments (fig. 2). These graminoids mostly consisted of sedges and rushes along with a few species of grasses typical of hydric sites. The high cover of graminoids in shelterwood treatment plots as compared to the other harvest treatments was possibly due to the lower residual basal area (which allowed high level of light at forest floor) in combination with the high moisture conditions (numerous small water pools for most of the year) created by harvest operations across the stand. Similar kinds of groundcover responses were observed in the clearcut gap portions of the group selection harvest plots where a relatively higher proportion of graminoids was also observed.

Total species richness values also differed between the uncut controls and harvested areas (fig. 3). Richness was lowest in the uncut control (only 21 genera) and as high as 40 genera in the third row thin treatment. Shrubs and graminoids typically represented the majority of all species. Group selection treatments had 39 genera, and other treatments had between 25 to 30 genera. The most dominant shrub species across all plots were giant gallberry (*Ilex coriacea*), muscadine (*Vitis rotundifolia*), fetterbush (*Lyonia lucida*), titi (*Cyrilla racemiflora*), and sweet pepperbush (*Clethra alnifolia*). The most common graminoids detected were *Andropogon glomeratus*,

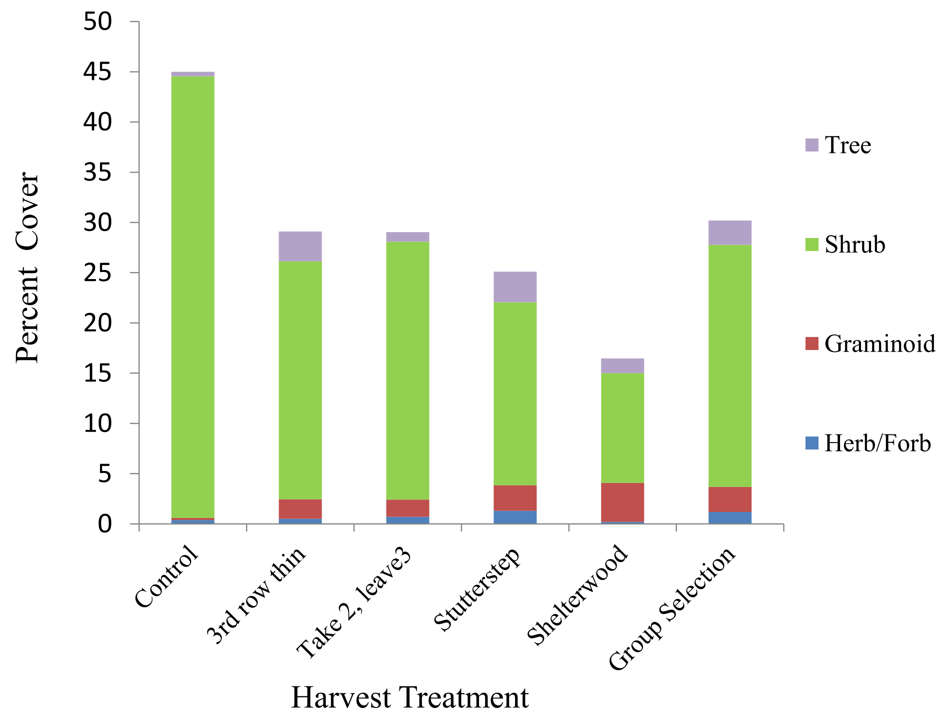


Figure 2—Percent cover and relative proportion of plant functional groups (forbs/herbs, graminoids, shrubs, and trees) observed in the groundcover one growing season following harvesting in slash pine plantations.

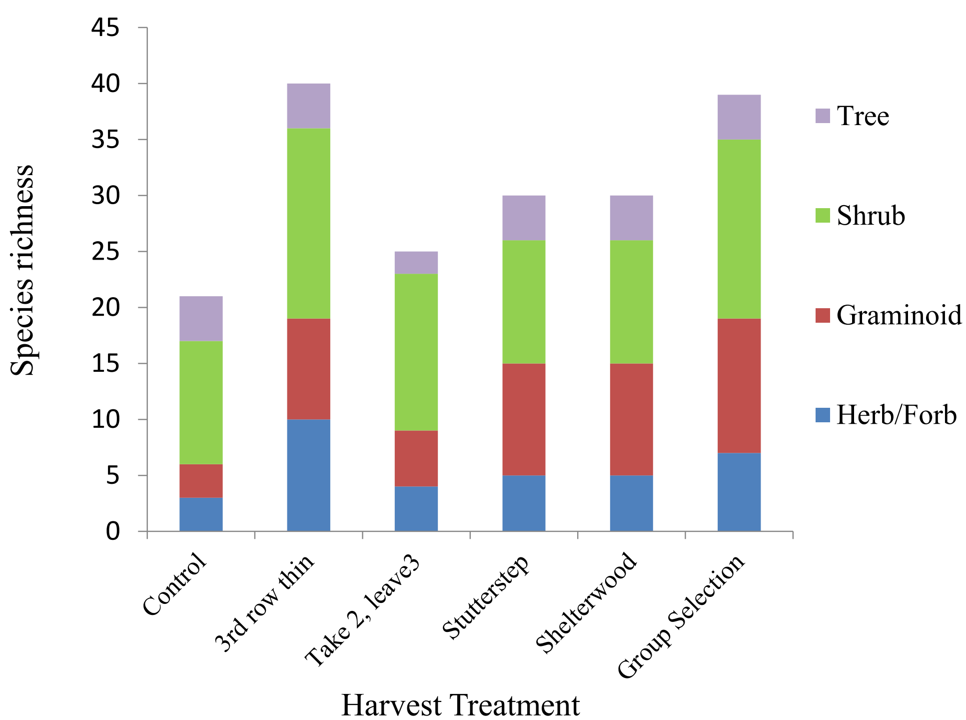


Figure 3—Total species richness across treatment plots by functional groups (forbs/herbs, graminoids, shrubs, and trees) observed one growing season following harvesting in slash pine plantations.

*Juncus dichotomus*, and *Rhynchospora* spp, and common forbs included *Drosera* spp., *Hypericum* spp., *Pteridium aquilinum*, and *Xyris* spp. Notably, yellow topped pitcher plants (*Sarracenia flava*) were also observed within the thinned rows of several treatment plots. Multi stemmed sprouts of sweetbay (*Magnolia virginiana*), blackgum (*Nyssa sylvatica*) and cypress (*Taxodium* spp) were the dominant tree regeneration aside from slash pine.

## CONCLUSIONS

The early response of slash pine regeneration and groundcover to the harvest treatments suggests that these harvest methods have potential to initiate reestablishment of slash pine regeneration and groundcover. However, these results are only early responses and mostly represent the effects of open canopy conditions and harvest related physical changes caused to the soil and vegetation cover, in particular decreases in the shrub component. The regeneration and groundcover dynamics have the potential for considerable changes as a burn regime is introduced, which might lead to high regeneration mortality, other successional changes in groundcover, and increased decomposition of the logging residues. Given the status of groundcover, logging residues, and the seedling size and distribution, we expect considerable mortality to the existing smaller regeneration due to the introduction of burn regime. However, heterogeneity in the microtopography across treatment plots may result in small pockets of protected regeneration following fire, particularly among larger sized seedlings that could withstand a rapid and cool surface fire. Additionally, prescribed burns may create post burn conditions conducive for seed germination and seedling growth by creating receptive mineral soil floor and reducing competition (Jose and others 2006), and groundcover responses may be desirable as burning has been observed to enhance herbaceous and graminoid cover (Jose and others 2006, Kush and others 2000, Lewis and Harshbarger 1976). The treatment plots in this study were just recently burned in November 2014 and a follow up assessment of regeneration and groundcover will determine effects of re introduced fire regimes in addition to harvesting.

## ACKNOWLEDGMENTS

Funding for the long term research project and installation of harvest treatments was provided by the Cooperative for Conserved Forest Ecosystems: Outreach and Research, with additional in kind support from the Florida Forest Service. David Morse, Forest Supervisor II for the Tate's Hell State Forest was particularly instrumental in facilitating harvest treatments. Funding for the post harvest regeneration and groundcover surveys was provided by the Florida Department of Environmental Protection.

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