EARLY DENSITY MANAGEMENT OF LONGLEAF PINE REDUCES SUSCEPTIBILITY TO ICE STORM DAMAGE

Timothy B. Harrington and Thaddeus A. Harrington[1]

Abstract—The Pax winter storm of February 2014 caused widespread damage to forest stands throughout the southeastern U.S. In a long-term study of savanna plant community restoration at the Savannah River Site, Aiken, SC, precommercial thinning (PCT) of 8- to 11-year-old plantations of longleaf pine (*Pinus palustris*) in 1994 reduced their susceptibility to stem bending and breakage from the storm 20 years later, despite the occurrence of an intensive commercial thinning just two years before the storm. Tree mortality in areas that had received PCT (25 percent) was less than where PCT had not occurred (40 percent). Incidence of heavy injury (e.g., crown loss of 75-99 percent, stem bent greater than 45 degrees) also was less with PCT (11 percent) than without PCT (16 percent).

INTRODUCTION

Prescribed fire and overstory density management are being used to restore and maintain the highly diverse savanna communities typical of longleaf pine (*Pinus palustris*) forests of the southeastern U.S. (Kilgo and Blake 2005). Without density management, fully-stocked stands of longleaf pine will competitively exclude understory herbaceous species (Mulligan and others 2002, Harrington 2011). However, timing of density management is critical because overstocked conditions can decrease tree stability (Oliver and Larson 1996). Differences in stand density do not directly influence susceptibility of southern pines to storm damage (Amateis and Burkhart 1996), but rather they result in changes in tree allometry (i.e., crown height, crown length, and stem slenderness) that impart greater risk when the stand is opened up by a subsequent disturbance, such as thinning. Recently thinned stands are particularly susceptible to toppling and breakage from ice storms (Bragg and others 2003).

This paper describes how density management treatments influenced the severity of ice-storm damage in a long-term study of longleaf pine savannas on the Savannah River Site. The Pax winter storm occurred during February 11-13, 2014 and affected most of the southeastern U.S. Glaze ice thickness was up to 1.25 inches in an area roughly centered over the Savannah River Site (National Weather Service 2014).

METHODS

The study was conducted at the Savannah River Site, a National Environmental Research Park near Aiken, SC. Detailed methodology and previous results are described in Harrington (2011). Study sites were selected to have fully stocked stands of longleaf pine with mid-story hardwoods. Six 8- to 11-year-old plantations of longleaf pine were located during winter 1993-94 having average stem densities of 600 pines and 240 hardwoods per acre. Soils include loamy sands of the Blanton, Lakeland, or Troup series with low to very low available water-holding capacities (Rogers 1990). Each site was divided into four treatment plots 7 to 17 acres in area. One of the following treatments was randomly assigned to each plot:

1. Nontreated.
2. Pine thinning. In May 1994, pines were precommercially thinned to leave a uniform spacing of trees at approximately half of the original stem density.
3. Woody control. In 1995 and 1996, several herbicide treatments were applied to virtually eliminate all non-pine woody vegetation.
4. Combined treatments of pine thinning and woody control.

The experimental design is a randomized complete block with six replications (sites) of the four treatments arranged as a 2 x 2 factorial (i.e., presence versus absence of pine thinning and woody control). Within each of the 24 treatment plots, 10 sample points were systematically located for measuring tree growth and injury. Convergence of pine crown cover in thinned and nonthinned treatments (Harrington 2011) prompted the need for a commercial thinning in early 2012 to

[1]Timothy B. Harrington, Research Forester, Pacific Northwest Research Station, U.S.D.A. Forest Service, 3625 93rd Ave. SW, Olympia, WA 98512; Thaddeus A. Harrington, Assistant Director for Research, Southern Forest Experiment Station and Northern Rocky Mountain Forest and Range Experiment Station (retired).

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.

rejuvenate the savanna communities. Treatments 2 and 4 were thinned to leave a pine basal area of about 40 square feet per acre (BA40), and treatments 1 and 3 were thinned to leave about 70 square feet per acre (BA70). To reduce fuel accumulations and abundance of non-pine woody vegetation, dormant-season prescribed fires were applied to each site every 3 to 5 years.

In September 2010, each pine located within 19.7 feet of a sample point was measured for diameter at breast height (dbh; nearest 0.04 inch at 4.5 feet aboveground). Following the commercial thinning in 2012, the radius of sampled area around each sample point was increased to maintain adequate tree sample sizes. In September 2012, each longleaf pine located within 29.3 feet of a sample point was tagged and measured for dbh. Stem diameter measurements were repeated in September 2013. In May 2014, each tagged pine was assessed for glaze-ice damage from the Pax winter storm. Trees were classified according to their degree of stem bending (less than 15 degrees, 15 to 45 degrees, or greater than 45 degrees), crown loss (0, 1-24, 25-49, 50-74, 75-99, or 100 percent), stem breakage (none, broken top, or broken stem), and uprooting (present or absent). Using these data, each tree was assigned to one of the following five injury classes:

1. None. No visual injury from the ice storm or stem bent less than 15 degrees.
2. Light. Crown loss 1-24 percent or stem bent 15 to 45 degrees.
3. Moderate. Crown loss 25-74 percent or presence of a broken top.
4. Heavy. Crown loss 75-99 percent, stem bent greater than 45 degrees, presence of a broken stem, or presence of uprooting.
5. Dead. Crown loss 100 percent.

All statistical analyses were limited to the longleaf pine component of the study. Loblolly pine (*Pinus taeda*) comprised about 4 percent of pine stem density and these data were excluded from the analyses. Stem density and stand basal area of longleaf pines were calculated for each sample point and then averaged by treatment plot. Each density variable was subjected to repeated measures analysis of variance (ANOVA) in SAS (SAS Institute, Inc., 2013) to test for fixed effects of thinning level, woody control level, year (2010, 2012, and 2014), and their interactions after adjusting for random effects of blocking. A natural logarithmic transformation was applied to each variable prior to ANOVA to improve the homogeneity of the residual variances. Multiple comparisons of treatment means were conducted with Tukey's HSD test using Bonferroni-adjusted probabilities to reduce the likelihood of Type I errors. All statistical tests were conducted with an alpha level of 0.05.

Injury class data for each treatment plot were expressed as a proportion of stand density (i.e., stem density or stand basal area) to remove inherent differences between thinning levels (after Amateis and Burkhart 1996). For each injury class, a mixed-model ANOVA was conducted on each density variable to test for fixed effects of thinning level, woody control level, and their interaction after adjusting for random effects of blocking. An angular transformation (arc-sine, square-root) was applied to each variable prior to ANOVA to improve the homogeneity of the residual variances. To illustrate treatment effects on longleaf pine damage, back-transformed, least-squares means for proportionate stem density and proportionate stand basal area by injury class were re-expressed in the original units of trees per acre and square feet per acre, respectively.

RESULTS

A total of 1,942 longleaf pines were included in the ice damage assessments. In 2010, 16 years after the precommercial thinning treatment, stem density of longleaf pines was greater in nonthinned stands than in thinned stands (353 versus 212 trees per acre, respectively), but stand basal area did not differ because of convergence of the two treatments (table 1). The commercial thinning of 2012 re-established the desired differences in stand density between the two thinning levels. However, mortality of longleaf pines from the Pax winter storm in 2014 was greater in BA70 (40 percent of stems) than in BA40 (25 percent of stems) (fig. 1), and as a result, stand basal area no longer differed between the two treatments.

For both stem density and stand basal area, proportionate injury differed between BA40 and BA70 for the following injury classes: none, light, heavy, and dead (fig. 1). There was a higher proportion of trees in BA70 than in BA40 for the non-injured, heavily injured, and dead classes; however, there was a lower proportion of trees for the light injury class. In addition, mortality of longleaf pines was lower in plots that received woody control (29 percent) than in those that did not receive the treatment (36 percent).

DISCUSSION AND CONCLUSIONS

In this long-term study of longleaf pine savanna restoration, precommercial thinning at ages 8 to 11 years resulted 20 years later in contrasting differences in plantation susceptibility to glaze ice damage. In the fourteenth year of the study (2008), crown height was 1.5 m greater and crown length was 1.1 m less in nonthinned stands than in thinned stands (Harrington 2011), resulting in greater top-heaviness and less overall stability for nonthinned stands.

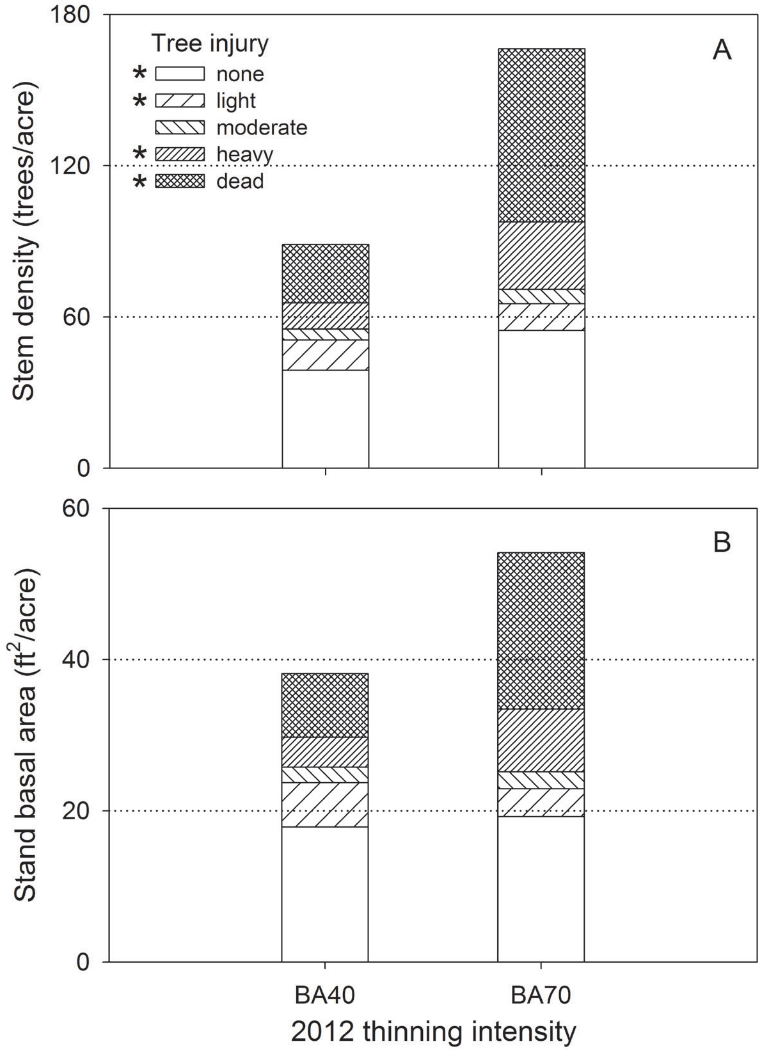

Figure 1—Effects of 2012 thinning intensity on: (a) stem density and (b) stand basal area of 28- to 31-year-old longleaf pine plantations by tree injury class three months after the February 2014 Pax ice storm at the Savannah River Site, Aiken, SC. For both stem density and stand basal area, asterisks (*) in the legend indicate injury classes that differed significantly (P<0.05) between thinning intensities.

The commercial thinning of 2012 opened up both thinned (BA70) and nonthinned stands (BA40) sufficiently to render them susceptible to stem bending and breakage from an ice storm. The Pax winter storm occurred just two years after the commercial thinning when the stands were still in a vulnerable stage. Had the storm occurred four or more years after thinning, injury and mortality likely would have been much less because the trees would have had sufficient time to become more stable with increased growth in stem diameter and slowed upward crown recession.

ACKNOWLEDGMENTS

Funding for this research was provided by the U.S. Department of Energy through the U.S. Forest Service, Savannah River. Special thanks for logistical assistance from U.S. Forest Service, Savannah River, especially John Blake, Ed Olson, and Paul Varnedoe. Thanks also to staff of PNW Research Station for assistance with the field work, especially James Dollins.

LITERATURE CITED

Amateis, R.L.; Burkhart, H.E. 1996. Impact of heavy glaze in a loblolly pine spacing trial. Southern Journal of Applied Forestry. 20: 151-155.

Bragg, D.C.; Shelton, M.G.; Zeide, B. 2003. Impacts and management implications of ice storms on forests in the southern United States. Forest Ecology and Management. 186: 99-123.

Table 1—Changes in stand density of longleaf pine plantations from 2010 to 2014 at the Savannah River Site, Aiken, SC. For a given variable and date, numbers followed by the same letter do not differ significantly (P<0.05)

		Date[a]		
Variable	Treatment[b]	September 2010	September 2012	May 2014
Stem density (trees per acre)	Nonthinned/BA70	353 a	168 a	92 a
	Thinned/BA40	212 b	92 b	66 b
Stand basal area (square feet per acre)	Nonthinned/BA70	88 a	54 a	32 a
	Thinned/BA40	72 a	38 b	30 a

[a] The second thinning occurred in early 2012 and the Pax winter storm occurred in February 2014.

[b] "Nonthinned" and "thinned" indicate the level of precommercial thinning that occurred in 1994, and "BA70" and "BA40" indicate the intensity of commercial thinning that occurred in 2012.

Harrington, T.B. 2011. Overstory and understory relationships in longleaf pine plantations 14 years after thinning and woody control. Canadian Journal of Forest Research. 41: 2301-2314.

Kilgo, J.C.; Blake, J.I., eds. 2005. Ecology and management of a forested landscape: fifty years on the Savannah River Site. Washington, DC: Island Press. 479 p.

Mulligan, M.K.; Kirkman, L.K.; Mitchell, R.J. 2002. *Aristida beyrichiana* (wiregrass) establishment and recruitment: implications for restoration. Restoration Ecology. 10: 68-76.

National Weather Service. 2014. February 2014 significant snow and ice storm. http://www.weather.gov/cae/Feb2014SnowIceEvent.html [Date accessed: April 3, 2015].

Oliver, C.D.; Larson, B.C. 1996. Forest stand dynamics. Update ed. New York: John Wiley and Sons, Inc. 520 p.

Rogers, V.A. 1990. Soil survey of Savannah River Plant area, parts of Aiken, Barnwell, and Allendale Counties, South Carolina. Washington, DC: U.S. Department of Agriculture Soil Conservation Service. 127 p.

SAS Institute, Inc. 2013. The SAS System for Windows, version 9.4. Cary, North Carolina.