

PLANTED LONGLEAF PINE STANDS IN THE FACE OF A TROPICAL CYCLONE

**Seth W. Bigelow, Andrew W. Whelan, Jeffery B. Cannon, Gregory Starr,
Christina L. Staudhammer, Gavin R. Kenney, and Steven T. Brantley**

EXTENDED ABSTRACT

Longleaf pine planting is widely recommended to southeastern landowners as an attractive practice that can provide income while helping to restore land to its historic ecological condition. Although longleaf pine is more wind resistant than other southern pines (Johnsen and others 2009, Rutledge and others 2021), planted stands can be vulnerable in tropical cyclones. These powerful windstorms may damage enough trees to result in substantial decreases in economic returns. A considerable body of knowledge exists on longleaf vulnerability in natural forests but means for predicting the vulnerability of plantations are not well developed. We surveyed planted longleaf pine stands throughout the area of greatest windspeeds of Hurricane Michael. Our goal was to develop a formula for predicting the proportion of damaged stems at a specified wind-speed, given knowledge about plantation development, soils, and landscape context.

Eighty-seven planted longleaf pine stands, age ca. 11 to 60 years, were assessed at locations in southwest Georgia and northwest Florida from 11 to 17 months after the passage of Hurricane Michael. The sample comprised 2,285 trees. We made a single visit to each plot, measuring diameter at breast height (d.b.h.), height, and damage of each tree in fixed radius plots to assess stand characteristics. We used aerial (NAIP) imagery from before the storm to identify proportion of each plot comprising adult or sub-adult trees within 300 m for a measure of wind exposure; tree cover was divided into arc segments corresponding to cardinal and ordinal directions. Maximum wind gust speed was estimated with the *Hurrecon* model based on data from the National Oceanic and Atmospheric Administration (Boose and others 2004). Estimated gust speed range was 26 to 96 m s⁻¹ (58-216 miles per hour).

A model of probability of tree damage was developed based on the data collected. Data were analyzed with a generalized linear mixed model, based on a binomial distribution with a logit transformation (response variable: undamaged and damaged). Damage types were any that would result in classification as “unacceptable growing stock” and included tip-ups, snapped trunks, and lean ≥10 degrees from vertical. Stand ($n=87$) was classified as a random effect. Statistical model terms included d.b.h., height, relative d.b.h. (d.b.h. relative to the plot mean d.b.h.), interaction between height and relative d.b.h., tall-tree cover in direction of maximum wind speed, and interaction between gust speed and d.b.h. The results indicated that, as expected, tree height and d.b.h. were strong predictors of

Author Information: Seth W. Bigelow, Assistant Scientist, The Jones Center at Ichauway, Newton, GA 39870, (current address) Tall Timbers Research Station and Land Conservancy, Tallahassee FL 32312; Andrew W. Whelan, Research Associate, The Jones Center at Ichauway, Newton, GA 39870; Jeffery B. Cannon, Assistant Scientist, The Jones Center at Ichauway, Newton, GA 39870; Gregory Starr, Professor, University of Alabama, Tuscaloosa, AL 35487; Christina L. Staudhammer, Professor, University of Alabama, Tuscaloosa, AL 35487; Gavin R. Kenney, Graduate Research Assistant, University of Alabama, Tuscaloosa, AL 35487; and Steven T. Brantley, Associate Scientist, The Jones Center at Ichauway, Newton, GA 39870.

Citation for proceedings: Willis, John L.; Self, Andrew B.; Siegert, Courtney M., eds. 2022. Proceedings of the 21st Biennial Southern Silvicultural Research Conference. Gen. Tech. Rep. SRS-268. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 262 p. <https://doi.org/10.2737/SRS-GTR-268>.

damage ($p < 0.001$ for both) but in opposite directions, taller trees were more likely to be damaged, but trees with large d.b.h. were less likely to be damaged. High gust speeds were correlated with damage ($p < 0.1$) and there was an interaction between gust speed and d.b.h. ($p < 0.01$) which indicated slightly increased probability of damage of smaller trees at high gust speeds (fig. 1A). Similarly, the largest trees within a stand (as indicated by relative d.b.h.) were less likely to be damaged than the smaller ones, but there was an interaction with height ($p < 0.01$) indicating that if the trees with largest d.b.h. within a stand are also the tallest trees they are likely to be damaged (fig. 1B). High windward cover from tall vegetation cover was correlated with decreased damage ($p < 0.05$; fig. 1C), and no effect of stand density was detected.

Attentive management of planted longleaf pine stands requires frequent thinning, which can be costly, so we scrutinized our results for support for the benefits of thinning. As a rule, removal of neighbors with thinning increases tree diameter growth but has little effect on height (Gonzalez-Benecke and others 2012). Although increased diameter should increase strength, stands have increased vulnerability to windthrow for up to 5 years after thinning (Dhôte 2005); we lacked data on thinning dates and were unable to test for this effect. The decrease in damage probability observed with larger d.b.h., and with larger relative d.b.h., supports the importance of thinning. Nevertheless, other studies show that the larger trees within a stand are most prone to damage and smaller trees within a stand are protected by larger ones (Hale and others 2012).

The observed increase in damage probability with increased height is a common finding in wind studies and is consistent with greater leverage exerted by taller trees with larger crowns (Gardiner and Quine 2000). We posit that frequent thinning may shrink the range of relative diameters in a stand and thereby provide some increased protection. Dhôte (2005) states that smoother canopies are advantageous for resisting windthrow, but he also found no clear improvement in tree stability in complex, uneven-aged canopies in comparison to even-aged monocultures (cf. Mason 2002). Our research suggests that row thinning should be combined with low thinning of overtopped and suppressed trees, along with limited crown thinning focusing on the tallest, emergent trees. Such trees are likely to have the highest turning moment and be most vulnerable to cyclonic winds.

Observations made in the aftermath of Hurricane Michael suggested that small-area pine stands (e.g., <0.1 ha) surrounded by open fields were highly vulnerable, and our analysis confirmed these observations. Windward tall-tree cover had a protective effect, suggesting that large-area planted stands and/or those planted to leeward of existing stands will be better protected from damage (Lohmander and Helles 1987). We were surprised not to observe a stronger effect of gust speed in our analyses, given that sampling locations in the eye of the storm path near the Gulf coast had >95 percent mortality. The relatively weak effect detected suggests the importance of multiple other factors such as stand and landscape effects that interact to determine damage to planted longleaf pine. Our research, which interprets field data via models, provides a basis for predicting damage probability which may be linked to geographic models of probability of experiencing cyclonic windspeeds near the Atlantic coast (Boose and others 2001, Zeng and others 2009). Our research also supports the role of professional management in creating planted longleaf pine stands that are resistant to cyclonic windstorms.

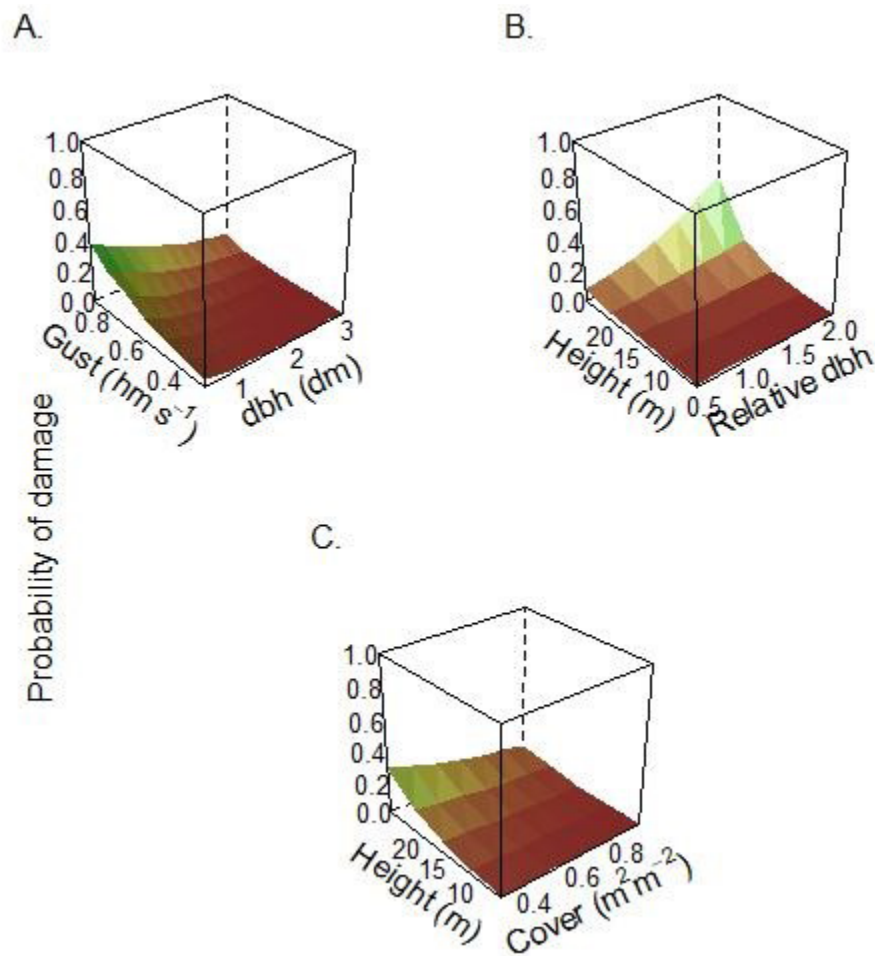


Figure 1—Predicted probability of damage to planted longleaf pines in windstorms (A) interactive effects of gust speed [100 m s^{-1} (hectometer, hm s^{-1}) units] and diameter at breast height (d.b.h.) [10 cm (decimeter, dm) units] shown here for trees 15 m tall (B) interactive effect of tree height and relative d.b.h. (d.b.h. divided by mean stand d.b.h.) (C) effect of tall-tree cover (to 300 m windward of plot) in conjunction with target-tree height.

LITERATURE CITED

- Boose, E.R.; Chamberlin, K.E.; Foster, D.R. 2001. Landscape and regional impacts of hurricanes in New England. *Ecological Monographs*. 71: 27–48.
- Boose, E.R.; Serrano, M.I.; Foster, D.R. 2004. Landscape and regional impacts of hurricanes in Puerto Rico. *Ecological Monographs*. 74: 335–352.
- Dhôte, J.-F. 2005. Implication of forest diversity in resistance to strong winds. In: Scherer-Lorenzen, M.; Körner, C.; Schulze, E.-D., eds. *Forest diversity and function: temperate and boreal systems*. Berlin Heidelberg Germany: Springer-Verlag: 291–307.
- Gardiner, B.A.; Quine, C.P. 2000. Management of forests to reduce the risk of abiotic damage—a review with particular reference to the effects of strong winds. *Forest Ecology and Management*. 135: 261–277.
- Gonzalez-Benecke, C.A.; Gezan, S.A.; Leduc, D.J. [and others]. 2012. Modeling survival, yield, volume partitioning and their response to thinning for longleaf pine plantations. *Forests*. 3: 1104–1132.
- Hale, S.E.; Gardiner, B.A.; Wellpott, A. [and others]. 2012. Wind loading of trees: influence of tree size and competition. *European Journal of Forest Research*. 131: 203–217.
- Johnsen, K.H.; Butnor, J.R.; Kush, J.S. [and others]. 2009. Hurricane Katrina winds damaged longleaf pine less than loblolly pine. *Southern Journal of Applied Forestry*. 33: 178–181.
- Lohmander, P.; Helles, F. 1987. Windthrow probability as a function of stand characteristics and shelter. *Scandinavian Journal of Forest Research*. 2: 227–238.
- Mason, W.L. 2002. Are irregular stands more windfirm? *Forestry*. 75: 347–355.
- Rutledge, B.T.; Cannon, J.B.; McIntyre, R.K. [and others]. 2021. Tree, stand, and landscape factors contributing to hurricane damage in a Coastal Plain forest: Post-hurricane assessment in a longleaf pine landscape. *Forest Ecology and Management*. 481(118724): 1–13.
- Zeng, H.; Chambers, J.Q.; Negrón-Juárez, R.I. [and others]. 2009. Impacts of tropical cyclones on U.S. forest tree mortality and carbon flux from 1851 to 2000. *Proceedings of the National Academy of Sciences*. 106: 7888–7892.