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Relationships between common forest metrics and realized impacts of Hurricane Katrina on forest resources in Mississippi

Sonja N. Oswalt *, Christopher M. Oswalt

U.S. Department of Agriculture, Forest Service, Southern Research Station, Forest Inventory and Analysis, 4700 Old Kingston Pike, Knoxville, TN 37919, United States

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Abstract

This paper compares and contrasts hurricane-related damage recorded across the Mississippi landscape in the 2 years following Katrina with initial damage assessments based on modeled parameters by the USDA Forest Service. Logistic and multiple regressions are used to evaluate the influence of stand characteristics on tree damage probability. Specifically, this paper addresses four primary questions related to post-hurricane damage: (1) do inventory data substantiate damage zone estimates made using remotely sensed and climate data following Hurricane Katrina; (2) were softwoods or hardwoods more susceptible to hurricane damage and does that susceptibility change as distance from landfall increases; (3) what are the primary stand-level factors influencing vulnerability to damage, based on observed damage and measured stand characteristics, and; (4) is tree-level damage related to tree species, and do damage types (bole, branch, lean, or windthrow) differ by species? We were able to accept the hypothesis that damage differed among the developed zones, and to confirm the acceptability of the figures initially generated. However, we were not able to accept the hypothesis that softwoods experienced more damage than hardwoods. Our data showed a marked increase in damage to hardwood species, except in the first zone of impact. Additionally, the likelihood of hardwood damage increased with increasing distance from the zone of impact. However, species group was confounded with the other predictor variables in many cases, making it difficult to separate the effects of each variable.
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Keywords: Hurricane Katrina; Forest; Inventory; Mississippi

1. Introduction

Hurricane Katrina made landfall in Plaquemines Parish, Louisiana on 29 August 2005. Katrina has been termed one of the most costly natural disasters in United States history, as well as one of the strongest hurricanes to make landfall on the U.S. coast in the last century (Graumann et al., 2005). In addition to hurricane-strength winds, Katrina brought massive amounts of rainfall over a very short timeframe, a storm surge of up to 8.5 m across southern Louisiana and Mississippi; extensive wind, rain, and related tornado damage throughout Mississippi, Western Tennessee and Western Kentucky; and extended hurricane-associated precipitation as far north as New York State (Graumann et al., 2005). Peak wind gusts associated with Katrina exceeded 80 km/h throughout the State of Mississippi (Graumann et al., 2005).

Damage assessment was an immediate priority for federal, State, and local governments. The U.S. Forest Service, Southern Research Station, Forest Inventory and Analysis program (USFS-SRS-FIA), among others, developed maps of damage zones using models developed by Jacobs (2007) to aid in damage assessment tasks (Fig. 1). Forest inventory data from 1994 were used in combination with the mapped damage zones to estimate damage potential and possible economic impacts across the State of Mississippi. Subsequently, zone maps and damage estimates were used by researchers and policy makers to aid in the development of recovery and salvage logging plans. Maps and estimates were used to further model hurricane effects on forest stands from the standpoint of individual-tree effects in order to suggest methods for reducing vulnerability to forests in hurricane impact zones (Stanturf et al., 2007). Therefore, estimates derived from models using available ground data, climate data, and remote sensing are important tools for forest management in a post-natural-disaster environment.

Initial estimates generated by USFS-SRS-FIA utilizing spatial models and 1994 inventory data indicated potential

* Corresponding author. Tel.: +1 865 862 2058; fax: +1 865 862 0262.
E-mail address: soswalt@fs.fed.us (S.N. Oswalt).

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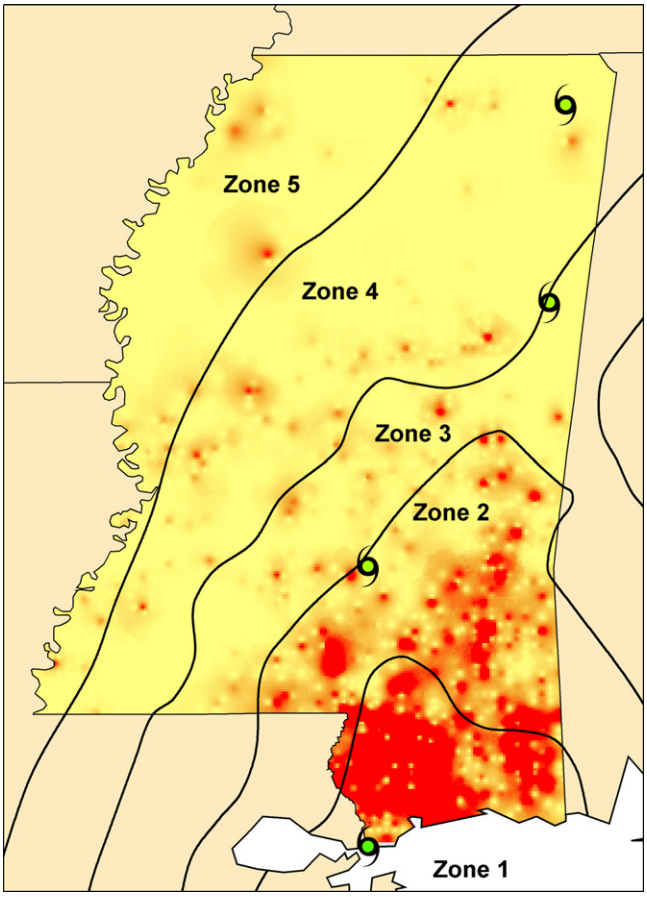

Fig. 1. Inverse distance weighting of percent trees ≥5 in. DBH damaged on FIA plots (dark shading) with an overlay of damage zones and Hurricane Katrina path. Hurricane path and damage zones were developed by Jacobs (2007).

timber losses of up to 84.9 million m^3 (3 billion ft^3) across 1.4 million ha of damaged forest land in Mississippi (USDA Forest Service, 2005). This equates to about 90% of standing timber in severe damage zones, and an average of 37% of standing timber across all damage zones (USDA Forest Service, 2005). Initial estimates (based on 1994 inventory data) suggested that more softwood volume was damaged than hardwood volume.

Using the USFS-derived damage zone information, combined with additional information from the Texas Forest Service, Stanturf et al. (2007) simulated equivalent hurricane forces to forecast stem breakage in a hypothetical set of nine softwood forest stands spanning an array of stand structure and density combinations. The resulting simulations suggested that stand spacing and tree height were more important in softwoods for determining stem-breakage potential than species, indicating that manipulating stand structure to reflect the least vulnerable conditions could aid landowners in decreasing the damage potential of forests in hurricane-impact zones (Stanturf et al., 2007).

Following Hurricane Katrina, the USFS-SRS-FIA began systematically sampling the forest resource across the entire State, following protocols outlined in the FIA sampling field guide (USDA Forest Service, 2005). One goal of the inventory was to determine the actual damage caused by Hurricane Katrina at the forest landscape and individual tree level. Here, we compare and contrast hurricane-related damage recorded across the Mississippi landscape in the 2 years following Katrina with initial damage assessments based on modeled parameters by USFS. We also use logistic and multiple regression to evaluate the influence of stand characteristics on tree damage probability to see if our data reflect the findings of Stanturf et al. (2007). Specifically, we address four primary questions related to post-hurricane damage:

1. Do inventory data substantiate damage zone estimates made using remotely sensed and climate data following Hurricane Katrina?
2. Were softwoods or hardwoods more susceptible to hurricane damage and does that susceptibility change as distance from landfall increases?
3. What are the primary stand-level factors influencing vulnerability to damage, based on observed damage and measured stand characteristics?
4. Is tree-level damage related to tree species, and do damage types (bole, branch, lean, or windthrow) differ by species?

2. Methods

2.1. FIA field methods

The USDA Forest Service FIA program collects data on systematically arranged plots at the scale of roughly one plot for every 2428 ha of land base. Each field plot consists of four subplots about 0.016 ha in size (for a total of 0.06 ha for each complete plot). Each plot is designated as ''sampled'' or ''not sampled'' and each subplot within each plot is similarly designated. Subplots may be divided if they are partially forested, a procedure referred to as ''condition mapping'' (Bechtold and Patterson, 2005). For this study, partially forested plots and plots with multiple conditions were removed from the dataset to avoid unnecessary mathematical complications. FIA protocols have been extensively described and documented, and those protocols will not be repeated here. Detailed descriptions of the plot design and variable collection techniques utilized here may be found online at http://srsfia2.fs.fed.us/.

Hurricane damage was collected on each forested FIA plot within the State of Mississippi, beginning on 11 November 2005. The data reported here reflect the most currently available data, which are incomplete for damage zones 4 and 5. Each plot was assigned a weather event code of 0 = no impact, 1 = impacted by a wind event, or 2 = impacted by heavy snow or ice. The weather event code was reduced to a binary variable of 0/1 where 0 = no wind event and 1 = wind event. Wind events were assumed to be related to Hurricane Katrina, whether directly through hurricane force winds, or indirectly through off-shoot tornado events.

On each plot where wind event = 1, individual trees received a damage code of 0/1 for damage absence or presence. Where individual tree damage = 1, each tree received a 0/1 code for bole damage (broken, twisted, or splintered) and windthrow