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Benefits and Limitations of Using Standard **Forest Inventory and Analysis** Data to Describe the Extent of a Catastrophic Weather Event

KaDonna C. Randolph

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The Author:

KaDonna C. Randolph, Mathematical
Statistician with the U.S. Department of
Agriculture Forest Service, Southern Research
Station, Forest Inventory and Analysis
Research Work Unit, Knoxville, TN 37919.

Cover photo

A glaze of ice from a winter storm covers white ash (*Fraxinus americana* L.).
(photograph by Joseph O'Brien, USDA Forest Service, Bugwood.org)

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ABSTRACT

Within the days and weeks following a catastrophic weather event, governmental forestry agencies often implement aerial reconnaissance missions to delineate damage zones. These initial rapid assessments are sometimes followed by on-the-ground surveys in order to verify the rapid assessments and more precisely quantify damage. When aerial or on-the-ground surveys are not feasible, data collected by the Forest Inventory and Analysis (FIA) Program of the Forest Service, U.S. Department of Agriculture, may be considered an alternative source of information to describe the extent and severity of damage. This study assessed the benefits and limitations of using standard FIA data to describe the geographical extent of damage from the January 2009 ice storm that left a glazing of up to 2 inches thick across the Central United States. Results demonstrated that standard FIA data may provide a suitable, though somewhat limited, substitute for rapid assessments conducted shortly after large-area catastrophic weather events.

Keywords: Central hardwood forest, disturbance, FIA, glazing, ice storm.

INTRODUCTION

Within the days and weeks following a catastrophic weather event, private landowners and government agencies typically conduct rapid assessments to delineate the geographical extent of the damage to the landscape. In the case of the forested landscape, government forestry agencies often implement aerial reconnaissance missions to delineate damage zones. When used in concert with available forest inventory data, the resulting maps allow land managers and other decisionmakers to quickly quantify potential losses and make decisions regarding disaster relief, timber salvage operations, and financial budgets. These initial rapid assessments are sometimes followed by on-the-ground surveys to more precisely quantify damage. Many such follow-up surveys have been conducted in cooperation with the Forest Inventory and Analysis (FIA) Program of the Forest Service, U.S. Department of Agriculture, which regularly measures a national grid of permanently located ground plots to estimate the extent and condition of forests at national, regional, State, and sub-State levels (Bechtold and Patterson 2005).

The FIA Program has conducted follow-up surveys with varying levels of intensity and rapidity. For example, the FIA Program initiated a special re-inventory of 2,530 plots following the landfall of Hurricane Hugo in September 1989 (Sheffield and Thompson 1992) and of 787 plots following an ice storm in January 1998 (Miller-Weeks and others 1999). Both of these surveys were completed within 6 to 9 months after each storm. These extraordinary re-inventories place additional demands on field crews and data managers, and are not always logistically or financially feasible. Therefore, some follow-up assessments are made during the regular FIA measurement cycle that follows the catastrophic event (Moser and others 2007, Oswalt and Oswalt 2008). In such cases, inventory plots may not be assessed until 5 or more years after the event.

During the regular inventory cycle, the FIA Program may intensify the collection of standard FIA variables (Moser and others 2007) or supplement the standard list of variables with additional descriptions of storm-related damage (e.g., percent crown loss and bole lean, bend, or breakage) (Miller-Weeks and others 1999, Oswalt and Oswalt 2008, Sheffield and Thompson 1992). As with the special re-inventories, data intensifications are not always conducted due to logistical and financial constraints. Therefore, the goal of this study is to assess the benefits and limitations of using standard FIA data to describe the geographical extent and severity of a catastrophic weather event. In this paper, "standard FIA data" refers to core FIA variables collected on the base grid during a regular inventory cycle (i.e., without additional efforts of special remeasurement, increased sampling intensity, and supplementary damage variables). Readers are referred to Bechtold and Patterson (2005) and USDA Forest Service (2011) for further details on the FIA sampling design.

The catastrophic weather event for this study is the January 26-28, 2009, winter storm that dropped a mix of rain, ice, and snow from Texas and Arkansas, across the Ohio River valley, and into New England. The type of precipitation that fell during this storm depended on local temperatures with areas on the warmer south side of the storm receiving rain, freezing rain, or sleet and areas on the north side of the arctic front receiving heavy snow (wet and dry). The middle region of the storm, from Oklahoma to West Virginia, was hit hardest with freezing rain and heavy, wet snow that left a glazing of ice up to 2 inches thick across the region (National Weather Service, no date).

Two ice-thickness glazing zones were delineated based on weather reports shortly after the storm[1] (fig. 1), and although the ongoing FIA inventory continued as usual following the storm, neither a rapid damage assessment nor a special follow-up inventory was completed within a short timeframe after the storm. As part of the regular FIA data collection protocols, field crews record the presence of weather disturbances on the forested ground plots. Using these records and the ice-thickness glazing zones, the objective of this study was to evaluate the effect of different areal delineations of the storm's extent on post-storm quantifications of ice damage in terms of percentage of live trees with broken boles.

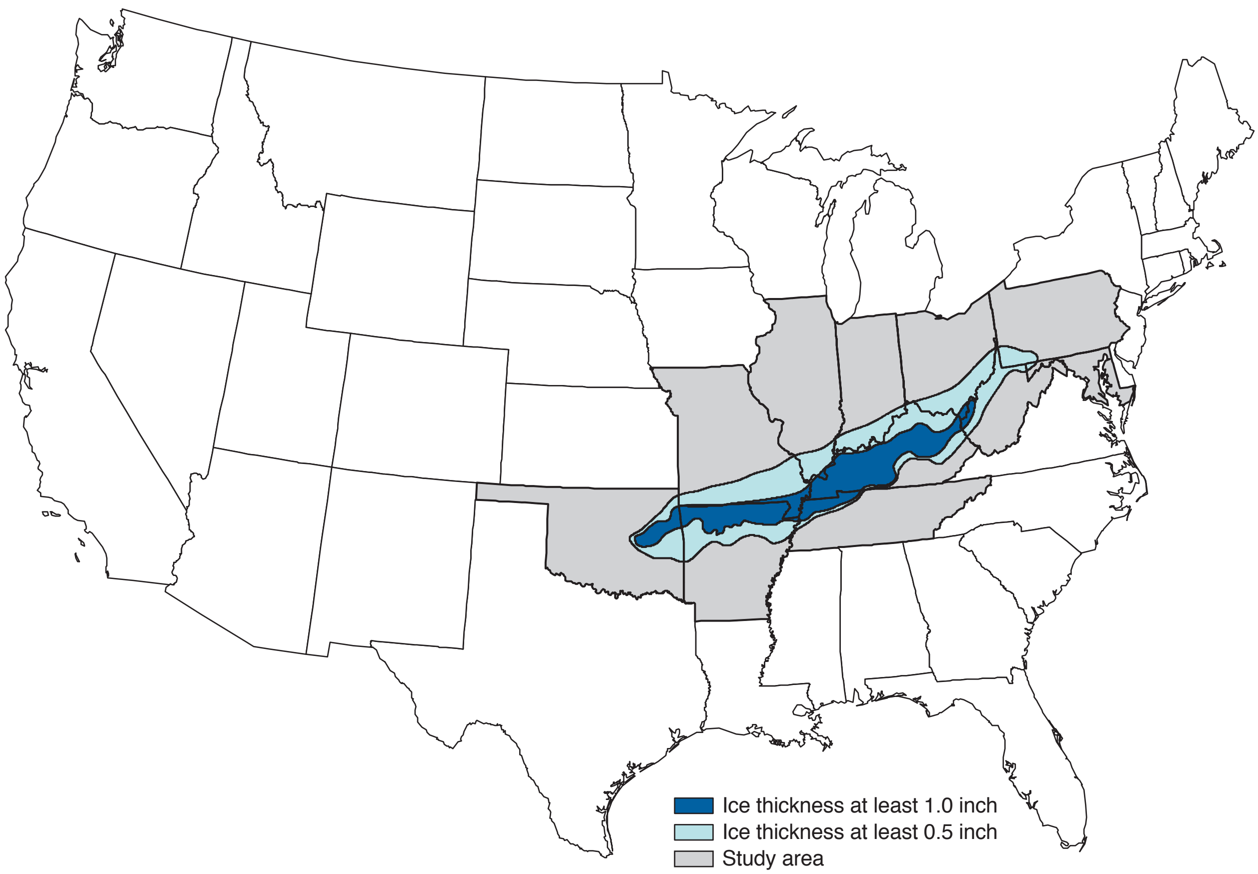

Figure 1—The middle region of the 11-State study area received freezing rain and heavy wet snow that left a glazing of ice up to 2 inches thick during the January 26-28, 2009, winter storm.

[1] Jacobs, D.J. 2010. Correspondence dated July 22 to KaDonna Randolph. On file with: U.S. Department of Agriculture Forest Service, Southern Research Station, 4700 Old Kingston Pike, Knoxville, TN 37919.

METHODS

Data Collection by the FIA Program

The FIA Program samples ground plots that are permanently located across the United States at a sampling intensity of one plot per approximately 6,000 acres (Bechtold and Patterson 2005). Plots consist of four 24-foot fixed-radius subplots on which tree stems ≥5 inches diameter at breast height (d.b.h.) are measured. When plots are partially forested, or straddle heterogeneous forest conditions, they are subdivided by a procedure known as "condition mapping" (Bechtold and Patterson 2005). Multiple conditions known as condition classes are distinguished on the basis of reserved status, owner group, forest type, stand size class, regeneration status, and tree density (USDA Forest Service 2011). Several ancillary attributes are used to further describe the condition classes but are not used to delineate new classes. Ancillary attributes relevant to this study are disturbance type and treatment type, and the year in which the disturbance or treatment occurred. Any number of condition classes may be recorded for each plot and up to three disturbances and up to three treatments may be recorded for any individual condition class (USDA Forest Service 2011).

In order for a condition class on any given plot to be categorized as "disturbed," the disturbed forested area encompassing the condition must be at least 1 acre in size and have mortality or damage to at least 25 percent of all trees in the stand or 50 percent of an individual tree species' count (USDA Forest Service 2011). For initial plot installations, the disturbance must have occurred within the last 5 years and for remeasured plots, the disturbance must have occurred since the previous inventory, typically 5 or 7 years prior in the Eastern United States and 10 years prior in the West (USDA Forest Service 2011). Qualifying damages are those that may prevent the tree from surviving more than 1 to 2 years, reduce the growth of the tree in the near term, or negatively affect the tree's marketable products. There are 10 main disturbance types that can be recorded for each condition: none, insect damage, disease damage, animal damage, weather damage, fire, human-caused damage, vegetation, geological disturbances, and unknown. The weather disturbance, which can be described more specifically as ice, wind (including hurricanes and tornadoes), flooding, or drought, is the only disturbance of interest for this study.

Treatments are considered a unique form of disturbance and must meet some of the same requirements in order to be recorded for a condition. That is, the treated area encompassing the condition must be at least 1 acre in size and have occurred within the last 5 years for initial plot installations or since the previous inventory for remeasured plots (USDA Forest Service 2011). In addition, the term treatment implies that a silvicultural treatment has been prescribed and does not include sparse removals for firewood, Christmas trees, or other miscellaneous purposes. Treatments that can be recorded are cutting, site preparation, artificial regeneration, natural regeneration, or other silvicultural treatment. Cutting was the only treatment considered to be of interest for this study.

For every tree ≥5 inches d.b.h., FIA field crews record several variables that describe its size, type, and condition. Of interest for this study were tree status (i.e., whether the tree is alive or dead), d.b.h., and tree length. Tree length is measured from the ground level to the top of the tree for all live trees. If the tree top is broken and completely detached from the tree (fig. 2), two lengths are recorded: (1) the length from ground level to the point of the break (actual length, L_A) and (2) the length from ground level to the estimated point where the top would be if it was not broken (total length, L_T). Often, the broken top is on the ground and available for direct length measurement. If not, the length of the broken portion is visually estimated based on the d.b.h. and species of the tree as well as the height of surrounding trees. L_A equals L_T for trees with intact tops (USDA Forest Service 2011).

Data Analysis

For this analysis, I utilized FIA plots measured in Arkansas, Illinois, Indiana, Kentucky, Maryland, Missouri, Ohio, Oklahoma, Pennsylvania, Tennessee, and West Virginia (fig. 1) within 36 months after the ice storm (i.e., February 2009 through January 2012). Plot-level, condition-level, and tree-level data from the post-storm assessment, along with matching data from the most recent pre-storm assessment, were obtained from the FIA database (O'Connell and others 2010). A geographic information system was used to delineate a 12.4-mile (approximately four-plot distance) wide buffer around the 0.5-inch to <1.0-inch ice-thickness glazing zone (fig. 3) and then to assign plots to one of four mutually exclusive areas of interest (AOI) (fig. 3): (1) within the zone receiving ≥1.0-inch ice glazing, (2) within the zone receiving at least 0.5-inch and <1.0-inch ice glazing, (3) within the 12.4-mile buffer, and (4) outside the 12.4-mile buffer and within the 11-State study area. Hereafter, these AOI are referred to as the 1-inch glaze zone, $^1/_2$-inch glaze zone, buffer zone, and outside the buffer zone, respectively. Assignment of the plots to these zones was done on the basis of both the confidential (i.e., actual) and publicly available (i.e., perturbed) plot coordinates maintained by FIA to examine the effect of the "fuzzing and swapping" procedure (McRoberts and others 2005) on the results.

Only trees that were alive pre- and post-storm with d.b.h. ≥5 inches and L_A=L_T at the pre-storm assessment were used in the analysis. Trees that were alive prior

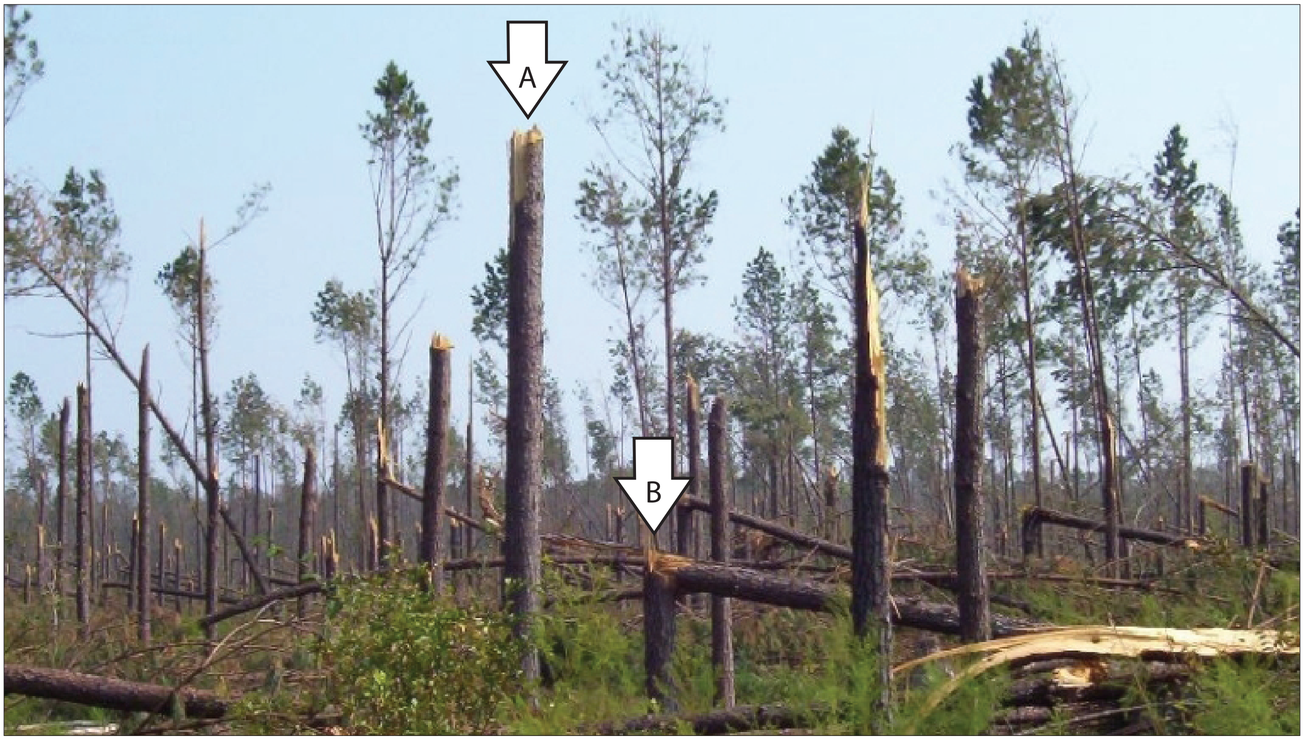

Figure 2—In order for a tree to qualify as having a missing top according to the FIA field guide, the top of the tree must be completely detached from the main stem (USDA Forest Service 2011). In this photo, tree A would qualify as having a missing top and both actual length and total length would be recorded individually. Tree B would not qualify as having a missing top and actual length would be equal to total length. (photo by Ricky Layson, Ricky Layson Photography, Bugwood.org)

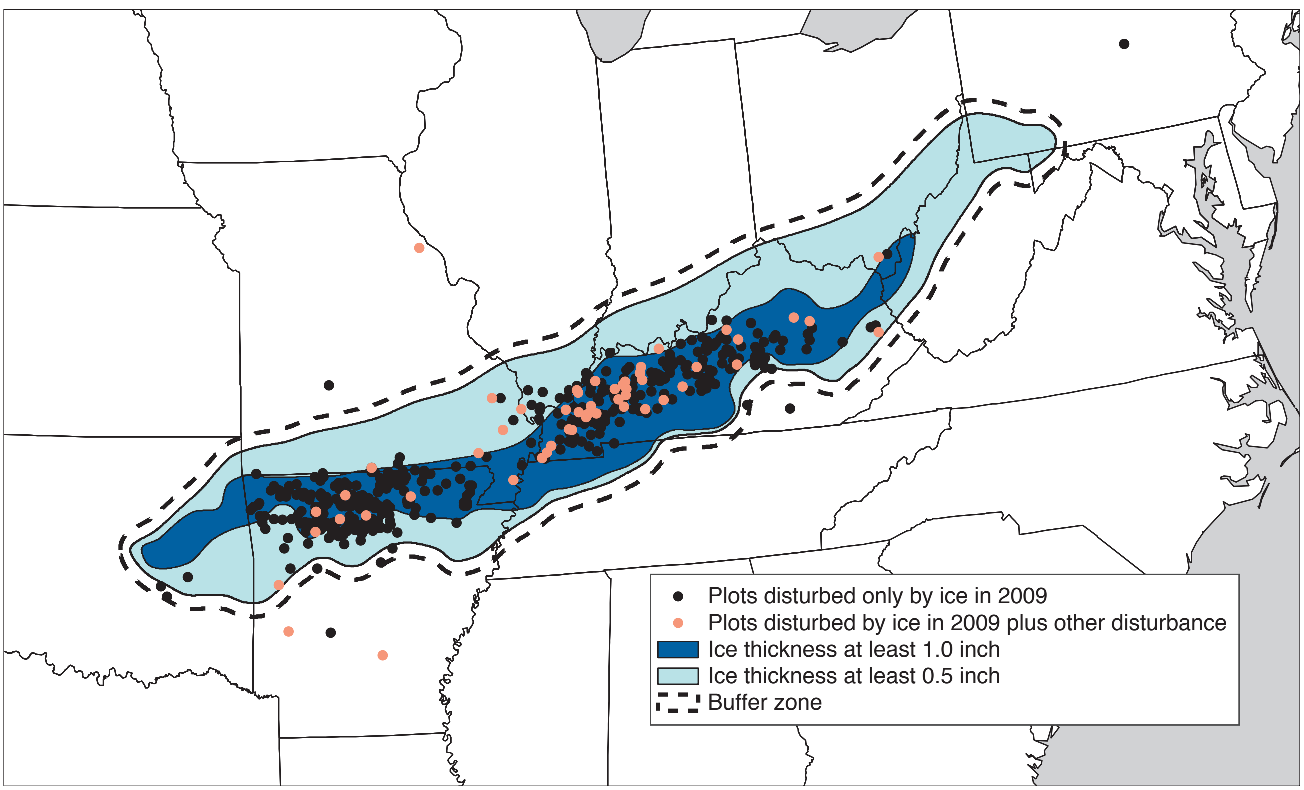

Figure 3—Most of the Forest Inventory and Analysis plots measured within 36 months after the January 2009 winter storm and for which field crews recorded a 2009 ice disturbance fell within the 1-inch and ½-inch glaze zones delineated from weather reports. (Plot locations are approximate.)

to the storm but cut and removed before the post-storm remeasurement were omitted because it was not known if those trees sustained damage from the storm prior to being removed. Trees that were alive prior to the storm but dead at the post-storm measurement were omitted because tree lengths for dead trees are optional measurements (USDA Forest Service 2011) and were not recorded for all dead trees. Tree lengths before the storm and after the storm were examined to determine the presence of a newly broken top. A newly broken top code was assigned to trees with L_A=L_T before the storm and L_A<L_T after the storm.

For each of the four AOI, plus the 1-inch and 1/2-inch glaze zones combined, three estimates were made with the ratio of means (ROM) estimator (Cochran 1977, Zarnoch and Bechtold 2000):

(1) The total number of newly broken trees per acre of forest land

(2) The total number of live trees per acre of forest land

(3) The percentage of trees with newly broken tops.

The total number of newly broken trees per acre of forest land ($\hat{R}$) was estimated as

$$\hat{R} = \frac{y}{x} = \frac{\sum_{i=1}^{n} y_i}{\sum_{i=1}^{n} x_i} \tag{1}$$

where

$$y_i = \sum_{j=1}^{c_i} I_{ij}\, y_{ij}$$

$$x_i = \sum_{j=1}^{c_i} I_{ij}\, x_{ij}$$

y_{ij} = count of the number of trees ≥5 inches d.b.h. alive before and after the storm with L_A=L_T before the storm and L_A<L_T after the storm tallied on plot i in condition class j

x_{ij} = area of plot i (acres) in condition class j

c_i = number of condition classes on plot i

I_{ij}=1 if condition class j on plot i is of interest or
0 if condition class j on plot i is not of interest

n = number of plots with at least one forested condition measured within 36 months after the storm in the States of interest

with estimated variance equal to

$$\hat{v}(\hat{R}) = \frac{1}{n\,(n-1)\,(\bar{x})^2}\left(\sum_{i=1}^{n} y_i^2 + \hat{R}^2 \sum_{i=1}^{n} x_i^2 - 2\hat{R} \sum_{i=1}^{n} y_i x_i\right) \tag{2}$$

where

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}$$

and all other variables as previously defined. The “condition class of interest” included all condition classes regardless of forest type, stand origin, etc. Note that the finite population correction factor in equation (2) has been ignored because the sampling fraction is negligible.

In like manner, the total number of live trees per acre of forest land ($\hat{R}'$) was calculated as

$$\hat{R}' = \frac{y'}{x'} = \frac{\sum_{i=1}^{n} y'_i}{\sum_{i=1}^{n} x'_i} \tag{3}$$

where

$$y'_i = \sum_{j=1}^{c_i} I_{ij}\, y'_{ij}$$

$$x'_i = \sum_{j=1}^{c_i} I_{ij}\, x'_{ij}$$

y'_{ij} = count of the number of trees ≥5 inches d.b.h. alive before and after the storm with L_A=L_T before the storm tallied on plot i in condition class j

x'_{ij} = area of plot i (acres) in condition class j

c_i = number of condition classes on plot i

I_{ij} = 1 if condition class j on plot i is of interest or
0 if condition class j on plot i is not of interest

n = number of plots with at least one forested condition measured within 36 months after the storm in the States of interest

with estimated variance equal to

$$\hat{v}(\hat{R}') = \frac{1}{n\,(n-1)\,\bar{x}'^2}\left(\sum_{i=1}^{n} y_i'^2 + \hat{R}'^2 \sum_{i=1}^{n} x_i'^2 - 2\hat{R}' \sum_{i=1}^{n} y_i' x_i'\right) \tag{4}$$

where

$$\bar{x}' = \frac{\sum_{i=1}^{n} x'_i}{n}$$

and all other variables as previously defined. The "condition class of interest" included all condition classes regardless of forest type, stand origin, etc. Note that the finite population correction factor in equation (4) has been ignored because the sampling fraction is negligible.

The percentage of trees with newly broken tops ($\hat{R}$*) was calculated as

$$\hat{R}^* = \frac{\hat{R}}{\hat{R}'} \tag{5}$$

with variance

$$\hat{v}(\hat{R}^*) = \hat{R}^{*2}\left(\frac{\hat{v}(\hat{R})}{\hat{R}^2} + \frac{\hat{v}(\hat{R}')}{\hat{R}'^2} - \frac{2cov(\hat{R}\hat{R}')}{\hat{R}\hat{R}'}\right) \tag{6}$$

where

$$cov(\hat{R}\hat{R}') = \frac{1}{n\,(n-1)\,\bar{x}\bar{x}'} \sum_{i=1}^{n}\left(y_i y'_i - \hat{R} y'_i x_i - \hat{R}' y_i x'_i + \hat{R}\hat{R}' x_i x'_i\right)$$

and all other variables as previously defined. A 95-percent confidence interval for $\hat{R}$* was calculated as

$$\hat{R}^* \pm 1.96\,(v(\hat{R}^*))^{0.5} \tag{7}$$

Throughout the remainder of this paper $\hat{R}$* is expressed as a percentage.

In addition to calculating $\hat{R}$* for the four AOI, an estimate of $\hat{R}$* was made for conditions solely disturbed by ice in 2009. That is, the "condition class of interest" was limited to conditions that were disturbed by ice in 2009 and had no other disturbance recorded during the post-storm assessment. This group of plots is referred to as the "ice-disturbed zone" and includes plots located in the 1-inch glaze zone, 1/2-inch glaze zone, and buffer zone (fig. 3). Conditions disturbed by ice and some other disturbance were excluded in order to minimize potential confounding effects of the other disturbances.

Standard hypothesis testing of the difference between $\hat{R}$* for the ice-disturbed zone and $\hat{R}$* for the other AOI was not performed because the estimates were not always completely independent of one another. Some, but not all, of the plots in the ice-disturbed zone were included in the other AOI and vice-versa (fig. 3). Instead of the standard hypothesis testing method, two ratios were declared significantly different from one another if their 95-percent confidence intervals did not overlap. The method of overlapping confidence intervals is known to reject the null hypothesis less often than the standard method, and in the presence of positive correlation, the method tends to be even more conservative and less powerful (Schenker and Gentleman 2001). Therefore, more significant differences may exist in reality than what is detected with this test, but no fewer. $\hat{R}$* for the various AOI were expected to rank according to the following inequalities: ice-disturbed zone ≥1-inch glaze zone > combined 1-inch and ½-inch glaze zone ≥ ½-inch glaze zone > buffer zone ≥ outside the buffer zone.

RESULTS

Across the 11-State region affected by the ice storm, the FIA Program measured 11,738 plots with at least one forested condition within 36 months after the storm. All conditions with a disturbance code of "ice" and a disturbance year of 2009 were assumed to have been damaged by the January 26-28 winter storm. A 2009 ice disturbance was recorded on 418 plots, 51 of which also had some other disturbance (fig. 3). The 51 plots with some other disturbance in addition to the 2009 ice disturbance, as well as four plots disturbed only by ice located beyond the buffer zone in Arkansas, Kentucky, Missouri, and Pennsylvania (fig. 3) were not included when $\hat{R}$* was calculated for the ice-disturbed zone. This resulted in a total of 363 plots in the ice-disturbed zone (table 1). The proportion of conditions in the ice-disturbed zone (i.e., with a disturbance code of "ice" and a disturbance year of 2009) that had been cut (3.3 percent) was slightly higher than the proportion of conditions cut in the 1-inch glaze zone (2.6 percent). Whether or not the greater proportion in the ice-disturbed zone was due to post-storm salvage operations is unknown. If the operations were salvage cuts, then $\hat{R}$* for the ice-disturbed zone may be underestimated.

The estimate of $\hat{R}$* for the ice-disturbed zone was 16.8 percent. As expected, this was the highest estimate of $\hat{R}$* among the AOI included in the study (table 1). The number of plots within the other AOI varied by plot coordinate basis (table 2), but the estimates of $\hat{R}$* remained the same to the nearest 1 percent with only slight variations in the 95-percent confidence limits (table 1). Overall, the estimates of $\hat{R}$* for the AOI generally ranked as expected, with the highest percentage of newly broken trees occurring in the ice-disturbed zone and lowest percentage occurring outside the buffer zone. Based on the method of overlapping confidence intervals, the rank ordering of the AOI based on the actual plot coordinates can be stated as follows, where inequalities indicate significantly different pair-wise comparisons at the 95-percent confidence level: ice-disturbed zone >1-inch glaze zone > combined 1-inch and ½-inch glaze zone > ½-inch glaze zone > buffer zone = outside the buffer zone. Likewise, the rank ordering of the AOI based on the perturbed plot coordinates was: ice-disturbed zone >1-inch glaze zone > combined 1-inch and ½-inch glaze zone > ½-inch glaze zone = buffer zone > outside the buffer zone.

DISCUSSION

Benefits of Using Standard FIA Data

An advantage of using FIA data for describing the extent of a catastrophic weather event is that such events typically affect an area that encompasses multiple States. For example, 195 counties across seven States were declared disaster areas after the January 2009 ice storm (FEMA 2013). For a variety of reasons, coordinating damage assessments across geopolitical boundaries is often not feasible. As a national program, FIA collects and makes publicly available (http://www.fia.fs.fed.us/tools-data/) data that are consistent across State borders.

Limited access to actual FIA plot coordinates has prompted several studies examining the effect of perturbed coordinates on the outcomes of spatially explicit research questions. Results have shown that using perturbed instead of actual plot coordinates has variable effects on the outcomes of different investigations. For example, studies that use FIA plot data in conjunction with satellite imagery or other spatially explicit data (e.g., digital terrain data) are affected most by the perturbed plot coordinates (Coulston and others 2006, Prisley and others 2009). In other studies, such as those making estimates or building models for large areas, the effect of using perturbed plot coordinates is typically negligible (Guldin and others 2006, McRoberts and others 2005, Prisley and others 2009). Results from this study partially affirmed the acceptability of using perturbed plot coordinates when making large-area estimates because plot coordinate basis only minimally affected the estimates of $\hat{R}$* for the geographically delineated AOI (table 1). However, slight shifts in the 95-percent confidence limits of the $\hat{R}$* estimates affected the results of the pairwise comparisons between the buffer zone and two other AOI, the ½-inch glaze zone and the outside the buffer zone.

Limitations of Using Standard FIA Data

Estimating the type and severity of forest damage sustained during a large-area, catastrophic weather event requires a geographical delineation of the event's impact zone. Conducting aerial surveys and analyzing weather data associated with the event are common ways of delineating such zones. Disturbance data collected by the FIA Program provide an additional way of delineating impact zones when other assessments are not feasible. However, because FIA data quality objectives (Pollard and others 2006) require disturbances to exceed size and severity thresholds before they can be noted as "present" at any given inventory location, estimates of damage based solely on the FIA disturbed conditions may be biased. As demonstrated in this study, the estimated proportion of trees sustaining broken tops from the January 2009 ice storm was significantly higher in the ice-disturbed zone (i.e., the zone

Table 1—Estimates of the total number of live trees (≥5 inches d.b.h.) per acre of forest land with newly broken tops ($\hat{R}$), total number of live trees (≥5 inches d.b.h.) per acre of forest land ($\hat{R}'$), and the percentage of trees with newly broken tops ($\hat{R}^*$), by area of interest (AOI) and plot coordinate basis

AOI and plot coordinate basis	Plots	$\hat{R}$	$\hat{R}'$	$\hat{R}^*$	SE	LCL	UCL
	number	- - - *trees per acre* - - -		- - - - - - - - - - - *percent* - - - - - - - - - -			
Ice-disturbed zone	363	21.4	127.1	16.8	0.91	15.1	18.6
Actual coordinates							
1-inch glaze zone	1,267	10.3	117.9	8.8	0.40	8.0	9.5
1/2-inch glaze zone	2,302	3.9	120.0	3.2	0.14	3.0	3.5
1-inch + 1/2-inch glaze zone	3,569	6.1	119.3	5.2	0.17	4.8	5.5
Buffer zone	796	3.0	116.1	2.6	0.19	2.2	2.9
Outside the buffer zone	7,373	2.6	123.4	2.1	0.05	2.0	2.2
Perturbed coordinates							
1-inch glaze zone	1,260	10.3	118.0	8.7	0.40	7.9	9.5
1/2-inch glaze zone	2,304	3.9	120.1	3.3	0.14	3.0	3.5
1-inch + 1/2-inch glaze zone	3,564	6.1	119.4	5.1	0.17	4.8	5.5
Buffer zone	804	3.1	116.3	2.7	0.19	2.3	3.0
Outside the buffer zone	7,370	2.6	123.3	2.1	0.05	2.0	2.2

d.b.h. = diameter at breast height.
SE = standard error of $\hat{R}^*$.
LCL = lower 95-percent confidence limit of $\hat{R}^*$.
UCL = upper 95-percent confidence limit of $\hat{R}^*$.

Table 2—Contingency table showing the number of Forest Inventory and Analysis plots in each area of interest, by plot coordinate basis

	Perturbed coordinate basis				
Actual coordinate basis	1-inch glaze zone	1/2-inch glaze zone	Buffer zone	Outside buffer zone	Total
1-inch glaze zone	1,221	45	1	0	1,267
1/2-inch glaze zone	39	2,231	30	2	2,302
Buffer zone	0	25	739	32	796
Outside the buffer zone	0	3	34	7,336	7,373
Total	**1,260**	**2,304**	**804**	**7,370**	**11,738**

delineated by the FIA disturbance codes) than in the 1-inch and 1/2-inch glazing zones based on weather data (table 1). A similar effect was evident in the Boundary Waters Canoe Area Wilderness following the July 1999 straight-line windstorm (derecho) where post-storm standing volume on wind-disturbed FIA plots was significantly lower than post-storm standing volume on undisturbed FIA plots inside a 3-mile buffer area surrounding and including blowdown areas delineated via satellite imagery (Moser and others 2007). Thus, the direction of the bias (overestimation or underestimation) will depend upon the variable being estimated (e.g., geographical area, broken stems, downed wood, etc.). The magnitude of the bias will depend upon how far beyond the disturbed plots low-level damage extends. The importance of any bias will depend upon the nature of the disturbance and the consequences of the damage, and may result in the omission of important areas for subsequent monitoring or management (e.g., for insect outbreaks or fuels reduction).

In addition to the potential bias, there are other limitations to using standard FIA data for describing damage from catastrophic weather events. First is the length of time after the event that one must wait until data are collected and made available. FIA plots within each State are divided into five panels. Ideally, one panel is collected each year so that over a period of 5 years all plots are visited. Once all five panels are collected, the cycle of remeasurement begins and continues ad infinitum (Bechtold and Patterson 2005). (Note: Some States collect data on a 7- or 10-year cycle.) Thus it is not until at least 5 years after an event that all plots within a large geographical area such as a State will be visited. The spatially balanced nature of plot locations (Bechtold and Patterson 2005) minimizes the potential of underestimating the geographical extent of a disturbance when only a portion of the plots in a complete cycle are utilized. However, the time lag introduces the possibility that damage attributed to the storm event may have been caused by a subsequent, or even preceding, disturbance. For example, the January 2009 ice storm occurred only 4 months after remnant storms from Hurricane Ike came through the area in September 2008 (Berg 2009) and was followed by a major derecho in May 2009 (Coniglio and others 2011). In an attempt to minimize confounding damages in this study, plots with multiple recorded disturbances were omitted from the ice-disturbed zone, but it is possible that some of the damage attributed to the ice storm on the remaining plots was the result of Hurricane Ike remnants, the derecho, or other local storms.

Another limitation to using standard FIA data for describing storm damage is the lack of explicit individual-tree damage descriptions. The standard FIA tree length variables L_A and L_T used in this study provided an estimate of only one of the most severe types of damage resulting from the storm, i.e., stem breakage. Minor to moderate branch breakage and stem bending, splitting, and uprooting are other common results of ice storms (Irland 2000). These types of damages were not accounted for in this study.

CONCLUSION

The FIA Program provides continuously updated and easily accessible standard forest inventory data that can be used to describe the extent of catastrophic weather events. The data cover all regions of the United States in a spatially balanced manner and can be related to other data sources (e.g., aerial photography and satellite imagery) through plot location coordinates. However, the utility of the standard FIA data is limited by issues of potential bias, lag times between the timing of the event and assessment, and lack of explicit individual-tree damage descriptors; although recent changes to field protocols may reduce the last limitation in future analyses (USDA Forest Service 2012). When rapid assessments cannot be made following a large-area catastrophic weather event such as an ice storm, standard FIA data may provide a suitable, though somewhat limited, alternative source of information. Researchers who wish to use FIA data for this purpose should carefully consider how these limitations may affect the outcome of their studies.

ACKNOWLEDGMENTS

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APPENDIX A

Glossary of FIA Terms

Condition class—The combination of discrete attributes that describe the area associated with a plot. These attributes include condition status (land use), forest type, stand origin, stand size, owner group, reserve status, and stand density, as well as other ancillary and computed attributes.

Core variable—All FIA regions produce a value for these variables and there is a prescribed national protocol for measuring or calculating these variables.

Cycle—One sequential and complete set of panels.

Forest type—A classification of forest land based upon and named for the tree species that forms the plurality of live-tree stocking. A forest type classification for a field location indicates the predominant live-tree species cover for the field location; hardwoods and softwoods are first grouped to determine predominant group, and Forest Type is selected from the predominant group.

Forest-type group—A combination of forest types that share closely associated species or site requirements.

Panel—A sample in which the same elements are measured on two or more occasions. FIA divides plots into five panels that can be used to independently sample the population.

APPENDIX B

Conversion Factors for Common Units of Measure

1 inch	=	2.54 centimeters
1 foot	=	0.3048 meter
1 mile	=	1.6093 kilometers
1 acre	=	0.404686 hectare

Randolph, KaDonna C. 2015. Benefits and limitations of using standard Forest Inventory and Analysis data to describe the extent of a catastrophic weather event. e-Res. Pap. SRS–55. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 10 p.

Within the days and weeks following a catastrophic weather event, governmental forestry agencies often implement aerial reconnaissance missions to delineate damage zones. These initial rapid assessments are sometimes followed by on-the-ground surveys in order to verify the rapid assessments and more precisely quantify damage. When aerial or on-the-ground surveys are not feasible, data collected by the Forest Inventory and Analysis (FIA) Program of the Forest Service, U.S. Department of Agriculture, may be considered an alternative source of information to describe the extent and severity of damage. This study assessed the benefits and limitations of using standard FIA data to describe the geographical extent of damage from the January 2009 ice storm that left a glazing of up to 2 inches thick across the Central United States. Results demonstrated that standard FIA data may provide a suitable, though somewhat limited, substitute for rapid assessments conducted shortly after large-area catastrophic weather events.

Keywords: Central hardwood forest, disturbance, FIA, glazing, ice storm.