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February 1994 Ice Storm: Forest Resource Damage Assessment in Northern Mississippi

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Cover photo—Winter-storm damage to a loblolly-shortleaf pine research watershed located on the Holly Springs National Forest in north Mississippi. Photo taken two weeks after the storm. Photo courtesy of the hydrology research unit in Oxford, MS.

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[a] All tables in this report are available in Microsoft® Excel workbook files. Upon request, these files will be supplied on 3½-inch diskettes.

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Abstract

During February 8–11, 1994, a severe winter storm moved from Texas and Oklahoma to the mid-Atlantic depositing in northern Mississippi a major ice accumulation of 3 to 6 inches. An assessment of forest resource damage was initiated immediately after the storm by performing an airborne video mission to acquire aerial imagery linked to global positioning coordinates. Interpretation of the aerial video imagery generated data that were used to map zones of similar damage severity. The Geographic Information System map data were linked with recent State forest resource inventory data to provide estimates of forest resource damage. There were 2.1 million acres of forest land within the 3.7-million-acre study area in northeast Mississippi. Less than 1 percent of the forest land remained untouched by some degree of damage. Net loss to live-tree volume, due to probable mortality, amounted to 16.5 percent of hardwoods and 15.3 percent of softwoods. The majority of volume loss occurred in areas that received about 25 percent mortality to the forest resource.

Keywords: Aerial reconnaissance, airborne video system, GIS, GPS, ice storm damage, isozone, Mississippi.

Introduction

During the late hours of February 8, 1994, an Arctic cold front moved southward into a developing moist weather system. While snow developed in the northern areas, sleet, snow, and freezing rain began to fall in east Texas and Louisiana. The storm system quickly developed heavy precipitation and was moved eastward by cold Arctic air to as far as Washington, DC. It dissipated over the Atlantic seaboard on February 11.

This was the worst ice storm to occur in Mississippi since January 1951 (NOAA 1994). Precipitation totaling as much as 8 inches moved across northern Mississippi on February 9, bringing ice accumulations of 3 to 6 inches over much of the area. Ice accumulation on power lines and trees caused some areas of the State to be without electrical power for more than a month. Timber damage was estimated at $1.3 billion, although Mississippi's timber harvest (most valuable agricultural commodity in Mississippi) continued apace—$1.02 billion in 1993, $1.07 billion in 1994, and $1.10 billion in 1995 (Daniels 1995, 1996).

The Mississippi Forestry Commission conducted aerial reconnaissance of the area immediately to determine the extent of storm damage. Portions of 32 counties had been affected. The forestry commission then asked the U.S. Department of Agriculture, Forest Service, Southern Research Station, Forest Inventory and Analysis Research Work Unit (FIA) in Starkville, MS, to determine the extent of damage to forest resources. The storm deposited a large amount of ice on the forest canopy, resulting in massive canopy destruction and a significant loss of timber volume. The forestry commission needed to develop fire-hazard mitigation plans for the new fiscal year almost immediately. A determination of the heavy fuel load created by canopy damage was therefore necessary. The timber damage also appeared to have compromised the integrity of the FIA 1994 forest inventory of northern Mississippi, which was completed in the fall of 1993 (Faulkner and others 1993). Our objectives were to generate damage-severity maps of the area and combine the damage estimates with recent State survey data to provide estimates of affected forest area and resource damage.

Our study was limited to the more heavily forested northeast Mississippi region, covering portions of 18 counties; we did not assess damaged forest area in the Mississippi River Alluvial Plain known as the Delta, where timber is sparse.

Background

Several catastrophic natural events have occurred in Mississippi over the past several decades. We used various reconnaissance techniques to assess damage to the area's natural resources. One such catastrophic event occurred on August 17, 1969, when Hurricane Camille moved inland from the Gulf of Mexico, resulting in damage totaling 290 million cubic feet of growing stock throughout 15 counties in southern Mississippi (Van Hooser and Hedlund 1969). Because we had completed a field inventory of the affected area in 1967, we needed to assess the damage and update the field inventory data. We used aerial reconnaissance to delineate areas of damage and determine where ground measurements should be taken. We then developed a plan that included a sampling grid with plot locations spaced at a 4-mile interval.

Procedures we developed after Hurricane Hugo struck South Carolina on September 21, 1989, were significantly different from those we followed to conduct the Hurricane Camille assessment. In assessing damage from Hurricane Hugo (Sheffield and Thompson 1992), we used permanent FIA plots in 23 South Carolina counties and corresponding data from the 1986 field survey (Tansey and Hutchins 1988).

We developed a two-phase sampling plan that allows quick assessment of catastrophic events that affect the integrity of forest inventories. First, we fly a video mission to gather a sufficient sample of aerial imagery. These video sample data and corresponding geographic coordinates are used to determine damage severity and to map the damage using a Geographic Information System (GIS). Second, we combine assessment data with the most recent data from the State field inventory for the area. This technique provides an estimate of the forest resources damage, as well as the area of forest land and forest-type groups that are affected by the event. The immediate georeferencing techniques of Global Positioning System (GPS) and cloud cover situations play an important role in the decision to use airborne video in each large-scale damage assessment.

Aerial reconnaissance is usually performed to quickly assess the extent of damage due to catastrophic events. The portability of airborne videography equipment provides for acquisition of aerial imagery when performing the next phase of the damage assessment. The FIA uses airborne videography and GPS data to assess catastrophic events occurring in southern forests. The aerial video imagery is used to delineate areas of similar forest damage. Such damage zones are then linked to the FIA forest resource inventory groundplot data for estimates of resource damage.

Damage assessment methodologies using airborne video techniques were developed within days of Hurricane Andrew's landfall in southern Louisiana on August 25, 1992 (Jacobs and Eggen-McIntosh 1993). The Louisiana Office of Forestry made an immediate aerial reconnaissance of the hurricane-damaged area and requested that the FIA in Starkville, MS, perform a forest damage assessment. Three days after the storm had passed, we flew GPS-referenced airborne video transects over the affected area, totaling over 600 air miles of flight lines. According to the 1991 State inventory (Vissage and others 1992), the hurricane study area encompassed 4.2 million acres and contained 1.8 million acres of timberland. Most forest lands in the study area were in the Atchafalaya River Basin, which included predominantly hardwoods of the oak-gum-cypress forest type. Approximately 1.1 million acres of timberland received some degree of damage to merchantable tree volume.

We modified the techniques developed for our study of Hurricane Andrew and applied them to our analysis of the Mississippi ice storm study area. Because there was virtually no pine component in the hurricane study area, we had to distinguish ice storm damage for the pine and hardwood components separately. Visually, the damage processes of the two components differed during the deciduous winter season: hardwoods appeared somewhat less affected than pine.

In a study of three Mississippi watersheds that received damage, Halverson and Guldin (1995) determined that pines received more stem breakage than hardwoods. Those watersheds received 100 percent inventories before and after the ice storm. Their results showed that 72 percent of pines sustained stem breakage, whereas hardwoods sustained only 15 percent. The overall damage assessment indicated that 88 percent of pines were affected with some type of ice damage, but only 37 percent of hardwoods.

Methods and Procedures

Study Area

Although forest damage was severe and widespread from the Mississippi River to the Alabama State line, our study area included only the more heavily forested region in the northeast corner of the State. Land on the Delta in northwest Mississippi is mostly agricultural; there are few areas of forest land. Because of the difficulty in following airborne video transect procedures on such scattered tracts of forest land, we limited our study area to 3.7 million acres in the northeastern portion of the State. According to 1994 inventory data, 2.1 million acres of forest land were within the ice storm study area. Although the Hurricane Andrew study area was 4.2 million acres, it included less forest land.

The dominant oak-hickory forest type is found on about half of the timberland in the study area. Loblolly-shortleaf pine, oak-pine, and oak-gum-cypress forest types are found on most of the rest. Principal tree species for northeastern Mississippi include oaks, hickories, shortleaf pine, loblolly pine, redcedars, tupelo-gums, sweetgum, baldcypress, elms, red maple, yellow-poplar, ashes, and sugarberry.

Airborne Video Mission

Airborne video missions are designed somewhat differently from aerial photography missions. Aerial photography missions are designed to produce total coverage of a study area, whereas aerial videography is designed as a sampling tool. Video flight lines are flown on a metric grid that will provide a sufficient number of samples for the area studied, as well as a continuous video transect sample. For large study areas, video flight lines may be several kilometers apart. In a typical mission, recording a 100-meter swath along the flight line will produce images with high enough resolution to identify details within the canopy structure. A single video frame at this resolution will cover 0.75 hectare. If a wider swath is desired for broader areal ground coverage, and visualization of individual tree crowns is the desired component rather than canopy structure, the swath can be increased to 250 meters by flying at a higher altitude. This wider swath will provide a single video image of approximately 5 hectares.

The Mississippi Forestry Commission provided a State plane and pilot, we mounted the GPS-video system. Our plans were to acquire imagery on north-south airborne video transects nearly perpendicular to the path and isoline severity of the ice storm. We spaced flight lines at 9-mile intervals, as closely oriented to the 3- by 3-mile FIA plot location grid as possible.

Flying at altitude 660 meters and using the maximum zoom (66 millimeters) for the focal length of the camera lens, provided a video footprint of 88 by 66 meters (0.6 hectare = 1.5 acres) for each sample location. This area coverage for the video image was slightly larger than the ground area covered by a forest inventory field plot (0.4 hectare = 1 acre). The combination of flying altitude and focal length produced a ground-to-image resolution of 13.75 centimeters per picture element (5.4 inches per pixel).

Airborne Video System

The FIA airborne video system (Jacobs and Evans 1996) allows us to collect vertical aerial video imagery of forest lands when rapid response is necessary or preferred. The equipment is easily transportable and can be installed in an aircraft on the same day it is used. The system includes four main parts: (1) video camera head, (2) color video monitor, (3) GPS receiver, and (4) video recording unit with a small graphics computer board that generates text onto the video image, such as GPS coordinates, altitude, date, and time.

Video Sampling

With the 9-mile spacing of flight lines, we subsampled the vertical aerial video imagery along each flight line at a 1-mile interval. This provided 1- by 9-mile spacing and a 1-to-1 ratio to the 3- by 3-mile spacing of permanent FIA field plots.

We modified techniques developed during the assessment of forest damage from Hurricane Andrew to assess damage from the ice storm. Our sample spacing was slightly different but provides a sampling intensity equal to the number of forest video samples in the Hurricane Andrew study area (Jacobs and Eggen-McIntosh 1993). In the hurricane study, we used a 0.5-mile spacing along the flight line, captured forest and nonforest video frames, and interpreted the forest video frames for damage severity.

A tabular list of latitude coordinates was generated for 1-mile increments (0.8689762 minute of latitude). Coordinates were cross-referenced with GPS coordinates on each video frame, and location samples were selected accordingly. We might have selected coordinates at even increments of 1 nautical mile (1 minute of latitude), but such spacing would not have represented the 3- by 3-mile spacing of the FIA plots. Nonetheless, it became evident that choice of spacing may be somewhat irrelevant.

Our objective was to determine damage to forest resources. When we found a video sample location to be nonforest, we used the nearest forest video frame along the video transect as the sample location. Consequently, the number of sample locations was intensified beyond the 1-to-1 ratio; there were 579 forest video sample locations but only 344 FIA forest plots within the study area. This modified sample selection criterion provided forest samples within sparsely forested areas, although segments of some video transects showed no forest for up to 8 miles of flight line (fig. 1).

Encoded onto the video imagery in flight, GPS coordinates were used to label each of the 579 video frames during analog-to-digital conversion. For example, 34d21.0823n89d19.1079w is the digital file name of the video frame recorded at lat. 34°21.0823’ N, long. 89°19.1079’ W. Although GPS coordinate precision as written may suggest 15- to 18-centimeter accuracy, the single-fix position of each video frame is only accurate to the GPS standard of 100 meters 95 percent of the time. This accuracy value is further eroded by the orientation of the aircraft.

Damage Interpretation Procedures

The file names are easily input, as geographic coordinates, to a GIS map file in order to create a point cover of the video sample point locations and associated damage-condition attributes. These attributes and other assessment variables listed in the following tabulation were used to interpret aerial video imagery at each sample location.

A. Hardwood percent and midpoint value (percent)

1.	0–25	12.5
2.	25–70	37.5
3.	50–75	62.5
4.	75–100	87.5

B. Hardwood or pine merchantability

0. Premerchantable
1. Merchantable

C. Hardwood or pine volume damage (bole mortality)

0. No visible damage
1. 1 to 33 percent of timber volume downed (light)
2. 34 to 67 percent of timber volume downed (moderate)
3. Over 67 percent of timber volume downed (severe)

D. Live tree damage (form/crown damage)

0. No visible damage
1. Less than 50 percent of canopy damaged, or basal area affected by other form damage
2. More than 50 percent canopy damage

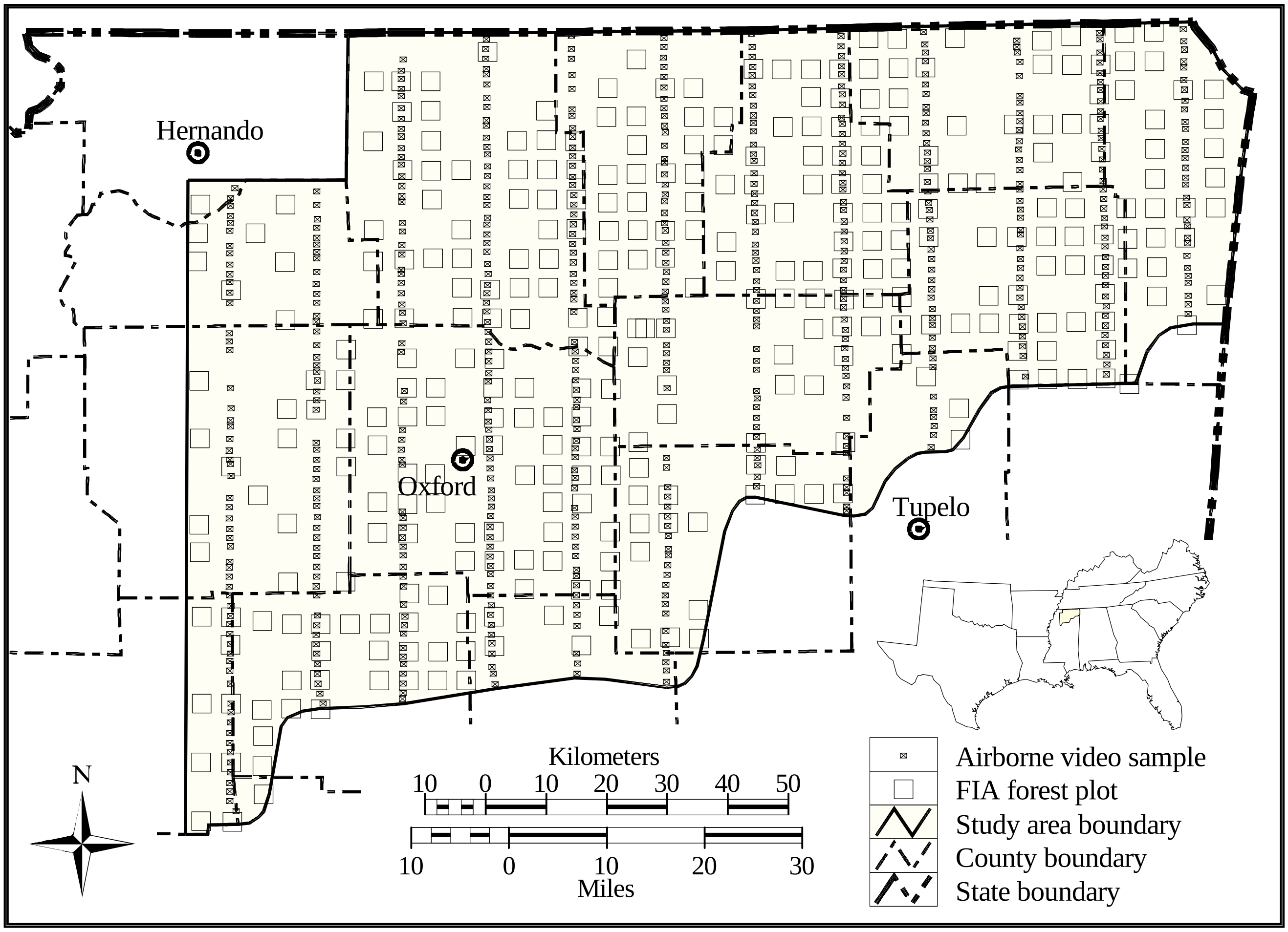

Figure 1—Study area of the February 1994 ice storm in northern Mississippi. Forested video sample locations and FIA ground plots are shown.

Each digital video image was interpreted for percentage of hardwood versus percentage of pine on a merchantable basal-area basis and grouped into one of four categories. Damage conditions were interpreted separately for each species group because pines are presumed to be more susceptible to ice damage than hardwoods. We used the merchantability variable to determine how many video sample locations had no mature timber in either species category. Canopy damage values could have been applied to the premerchantable species group on these video plots to determine probable stem mortality.

Because visual interpretation procedures can be considered highly subjective, we limited the damage categories to a tertiary breakdown for volume damage and a binary breakdown for canopy damage. Likewise, we continuously cross-referenced damage interpretation to other image samples to provide continuity across the study area.

We applied volume damage (bole mortality), indicating probable tree death, to merchantable timber only. In the final phase of the study, we applied these damage values to FIA volume and basal-area data. Live-tree damage was interpreted for the bole and crown. The crown damage variable indicated tree-form damage in live trees.

Mapping and Analysis

Geographic coordinates of the video samples and corresponding damage values were used to contour isolines for each forest type by similar forest damage. Figure 2 portrays the damage zones for hardwood volume and figure 3 for pine volume damage. Percent damage is represented by six values: 1 = 0 to 16, 2 = 17 to 33, 3 = 34 to 50, 4 = 51 to 66, 5 = 67 to 83, and 6 = 84 to 100. Figure 4 portrays total volume damage associated with the ice storm. Damage zones 5 and 6 were nonexistent, because bole damage of such severity occurred in isolated patches throughout the study area, and the damage was not broad enough to produce a distinct area of severe damage.

In aggregate, the mapping techniques (figs. 2, 3) depict widespread light-to-moderate damage throughout the study area for the hardwood and pine timber. The additive

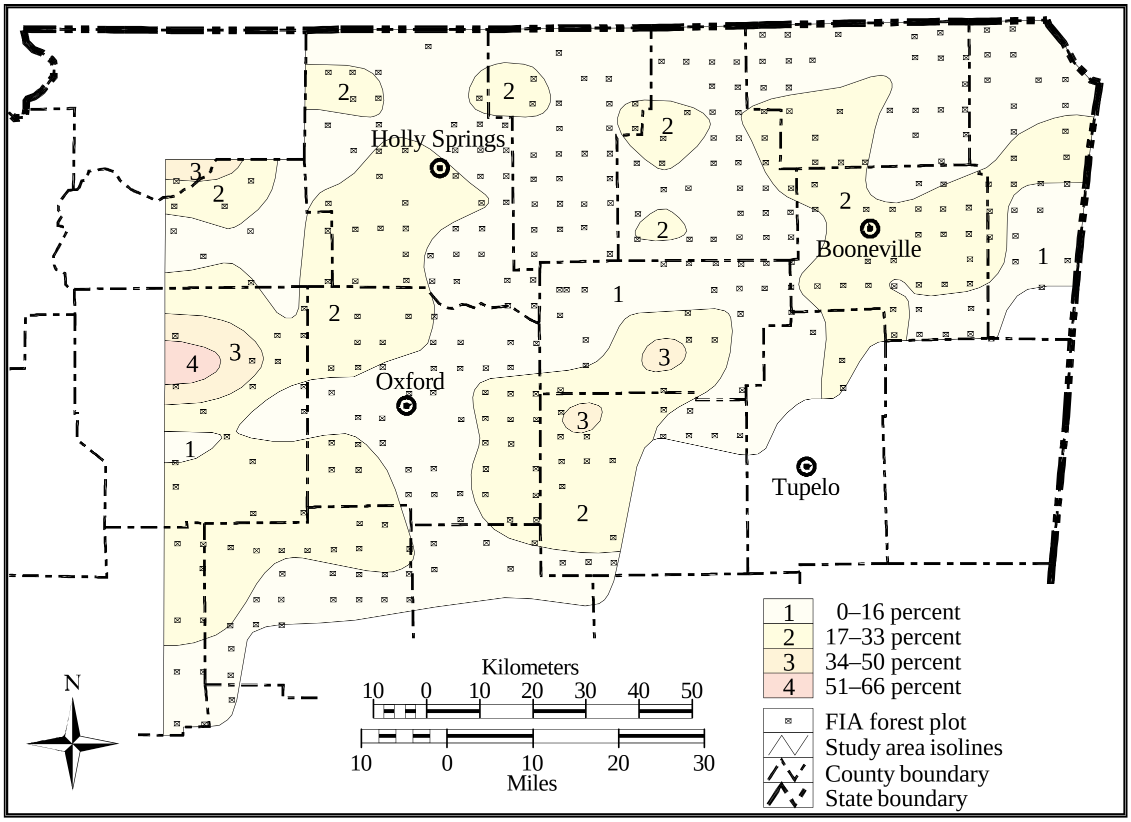

Figure 2—Hardwood volume damage of the February 1994 ice storm in northern Mississippi.

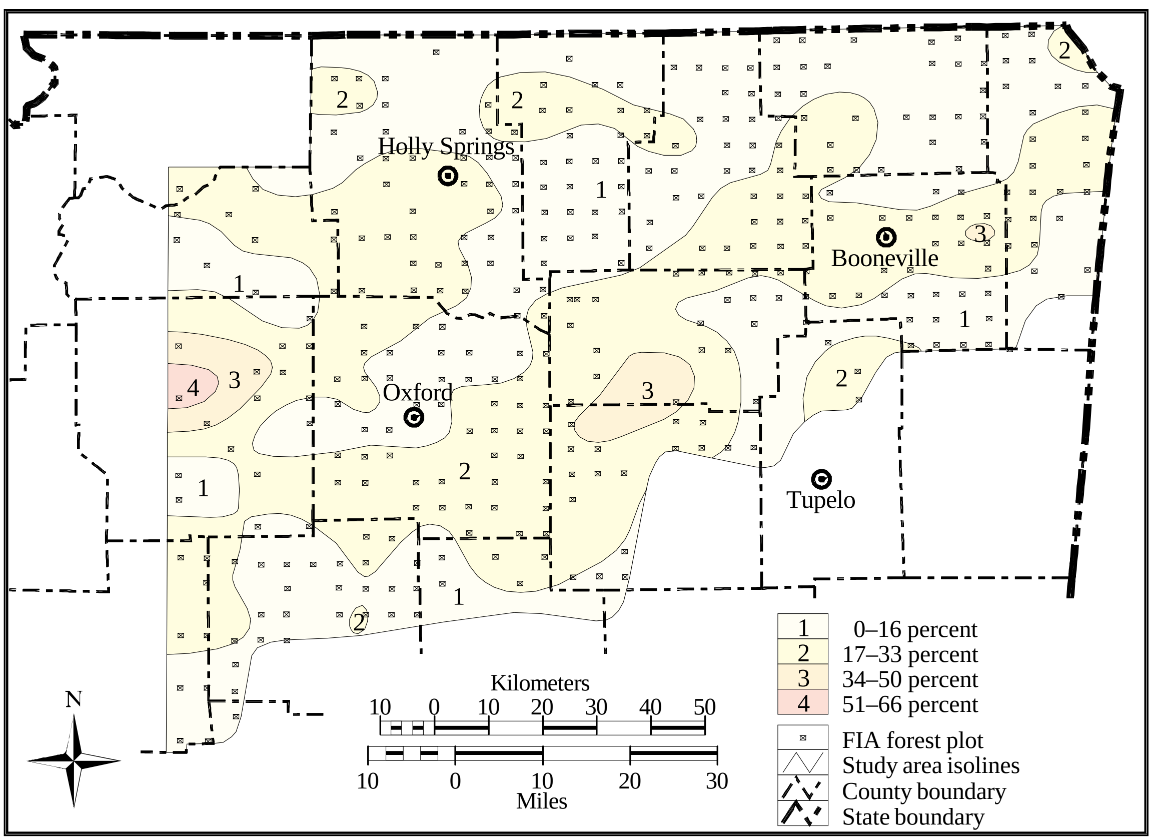

Figure 3—Softwood volume damage of the February 1994 ice storm in northern Mississippi.

effect of the damage shows up in figure 4 where isozone 2 covers a large segment of the study area and isozones 3 and 4 show collective hot spots of timber damage. At the edge of the Delta in isozone 4, timber damage is representative of areas throughout the Delta region. The storm's widespread damage explains why many houses were without electricity for up to 1 month after the storm.

Table 1 provides a breakdown of the video records by number of samples in each isozone. This dot-count method shows that the study area's hardwoods were 69 percent and pine 31 percent of the total damage, respectively.

Using the percent-hardwood midpoint variable, we developed a means of portraying the portion of timberland associated with hardwoods in each of four isozones (fig. 5). Comparably, FIA data show 71.1 percent basal area hardwood within the study area. Using mid-point percent values for each isozone in the GIS map coverage, we found that 70.4 percent of the timberland area was in hardwood (table 2). By comparison, Faulkner and others (1993) showed that unit 2 in north Mississippi contained 71 percent of the basal area in hardwood.

In figure 6 we used the percent-hardwood variable to portray pine associations. If damage had been uniform throughout the study area, figure 6 could have been used to identify areas receiving the heaviest damage because pine retains foliage during the winter season.

Table 1—Number of video samples by percent–hardwood assessment variable, February 1994 ice storm, northern Mississippi

Assessment variable	Variable midpoint	Video samples	Percent of total[a]	Hardwood[b]	Pine[c]
	Percent	*No.*		*Percent*	
1	12.5	59	10.2	1.3	8.9
2	37.5	68	11.7	4.4	7.3
3	62.5	117	20.2	12.6	7.6
4	87.5	335	57.9	50.6	7.2
Total		579	100.0	68.9	31.1

[a] Divide video samples by 579 to obtain percent of total.
[b] Multiply percent of total by variable midpoint to obtain hardwood percent.
[c] Multiply percent of total by (100 - variable midpoint) to obtain pine percent.
Data may not add to totals due to rounding.

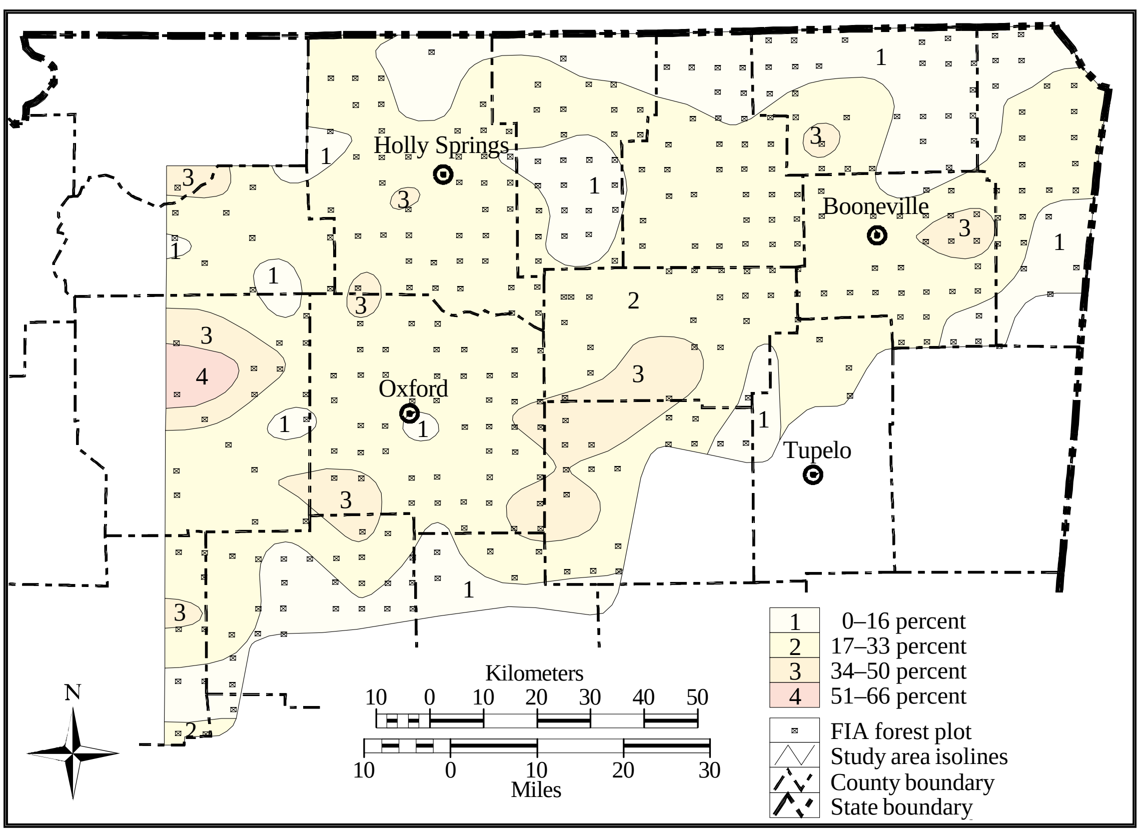

Figure 4—Aggregate volume damage of the February 1994 ice storm in northern Mississippi.

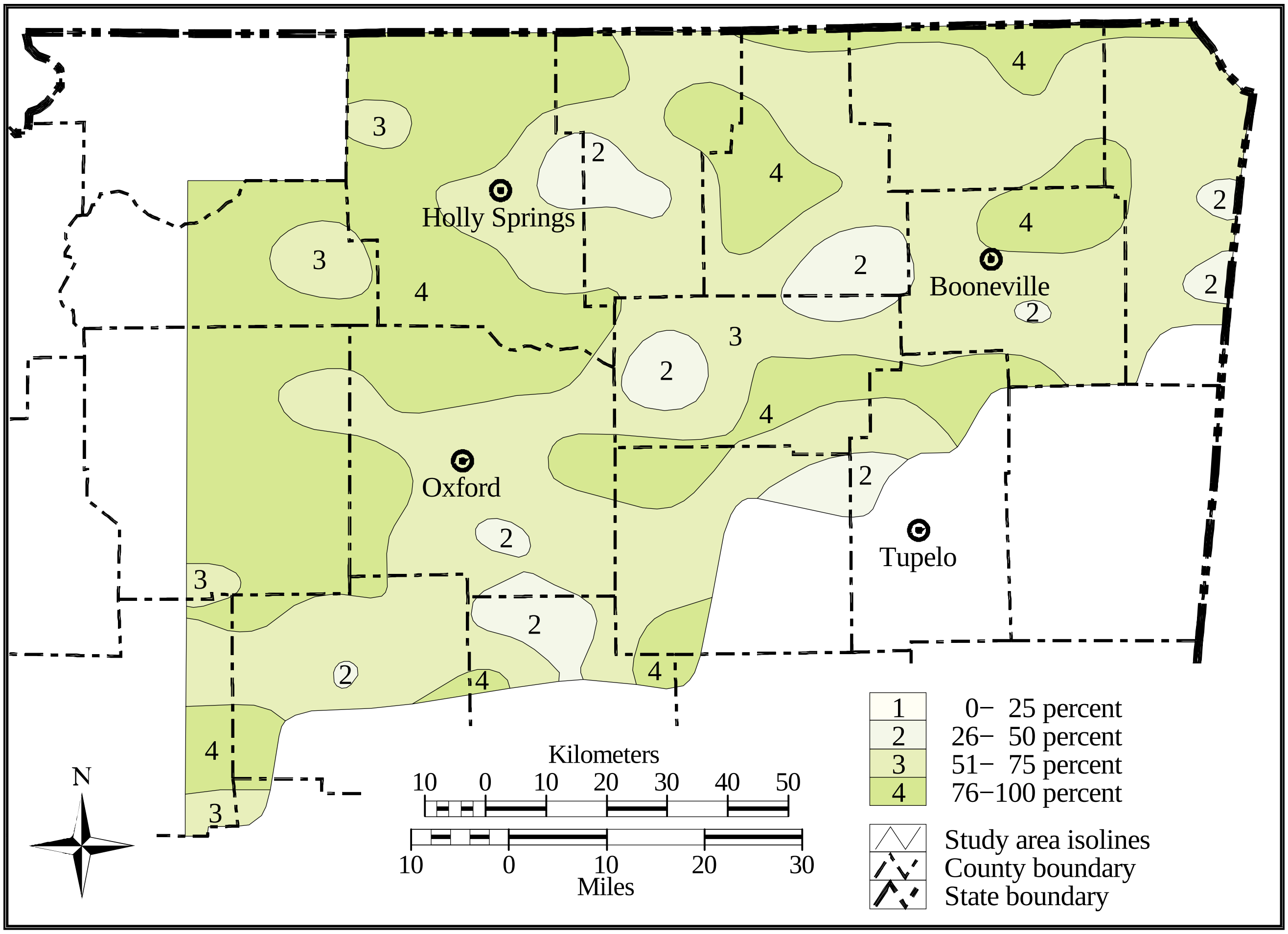

Figure 5—Proportion of timberland associated with hardwoods—derived from airborne video imagery.

Table 2—Timberland area associated with hardwood and pine isozones, February 1994 ice storm, northern Mississippi[a b]

Hardwood			Total area		Pine		
Hardwood isozone	Isozone midpoint	Hardwood	Isozone area	Percent of total	Pine	Isozone midpoint	Pine isozone
	- - - *Percent* - - -		*Thousand acres*		- - *Percent* - -		
1	12.5	0	0	0	0	87.5	4
2	37.5	2.9	282.0	7.7	4.8	62.5	3
3	62.5	33.1	1,936.0	52.9	19.8	37.5	2
4	87.5	34.4	1,441.0	39.4	4.9	12.5	1
Total		70.4	3,660.0	100.0	29.6		

[a] Pine isozones and midpoint percents are an inverse of hardwood.

[b] Multiply midpoint percent by percent of total area to obtain hardwood and pine percents of timberland area.

Data may not add to totals due to rounding.

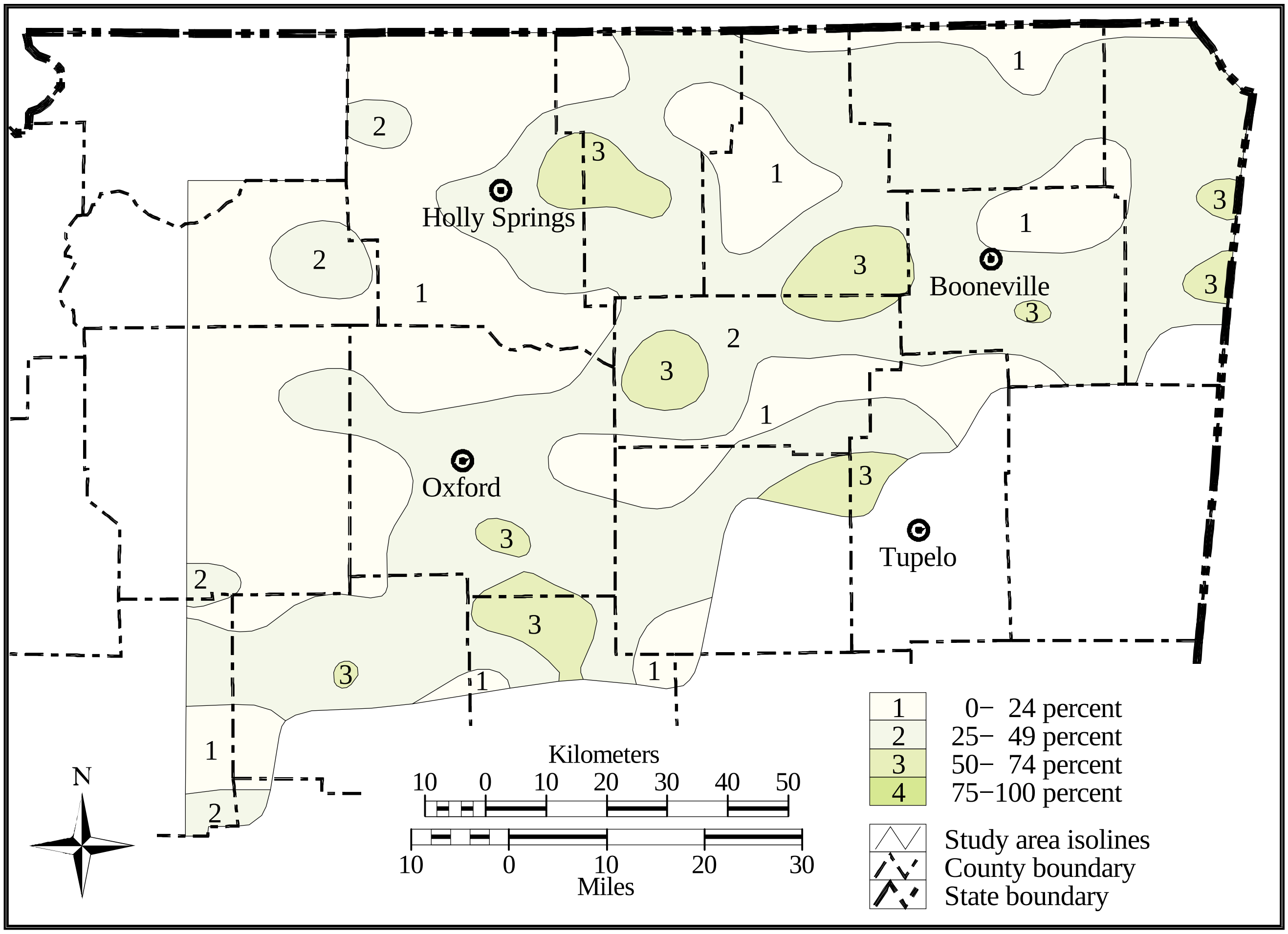

Figure 6—Proportion of timberland associated with softwoods—derived from airborne video imagery.

The GIS coverage for each hardwood and pine damage map (figs. 2, 3) identified FIA field inventory plots located within each damage component isozone. As a cross reference, video point data are summarized by damage class and damage zone for hardwood (table 3) and pine (table 4).

The study area includes 3,660,000 acres, 57 percent of which is in timberland (2,113,500 acres). Volume and area data from the latest FIA State survey (Faulkner and others 1993, Hartsell and London 1995) are correlated for the field plots that fall within each isozone. Figures 2 and 3

Table 3—Number of video samples by hardwood damage interpretation and zone, February 1994 ice storm, northern Mississippi

Damage zone	Video frame damage classification: No damage 0 percent	Light 1–33 percent	Moderate 34–66 percent	Severe 67–100 percent	Total
	Number of samples				
1 (Light)	116	228	3	0	347
2 (Light)	21	151	42	3	217
3 (Moderate)	0	3	8	1	12
4 (Moderate)	0	1	0	2	3
5 (Severe)[a]	0	0	0	0	0
6 (Severe)[a]	0	0	0	0	0
Total	137	383	53	6	579

[a] Damage zones 5 and 6 are nonexistent because the isolated patches of severe damage were not broad enough to produce isozones.

Table 4—Number of video samples by pine damage interpretation and zone, February 1994 ice storm, northern Mississippi

Damage zone	No damage 0 percent	Light 1–33 percent	Moderate 34–66 percent	Severe 67–100 percent	Total
	Number of samples				
1 (Light)	117	180	2	0	299
2 (Light)	36	162	53	10	261
3 (Moderate)	1	5	8	1	15
4 (Moderate)	0	1	1	2	4
5 (Severe)[a]	0	0	0	0	0
6 (Severe)[a]	0	0	0	0	0
Total	154	348	64	13	579

Video frame damage classification: No damage, Light, Moderate, Severe.

[a] Damage zones 5 and 6 are nonexistent because the isolated patches of severe damage were not broad enough to produce isozones.

correspond with table 5, which shows the breakdown of timberland area within each damage zone for the two maps.

Timberland areas for forest-type groups are derived from the FIA database and shown in tables 6 and 7. Damage values were determined separately for the hardwood and softwood species groups to provide different isolines and isozones for the two maps (figs. 2 and 3). Hence, we applied damage values for the hardwood damage isozones only to hardwood FIA data; the loblolly-shortleaf pine type is not shown in the hardwood table (table 6). Likewise, hardwood types are not shown in table 7 for the pine forest types.

We applied the midpoint damage values for each of the six isozones to FIA survey volume data to determine the net volume of live trees before and after the storm (table 8).

Table 5—Area by damage zone, February 1994 ice storm, northern Mississippi

Damage zone	Hardwood map: Isozone	Hardwood map: Timberland	Pine map: Isozone	Pine map: Timberland
	Thousand acres			
1	2,072	1,197.0	1,839	1,008.0
2	1,495	889.0	1,694	1,059.8
3	76	27.5	111	36.5
4	17	0	16	9.2
5	0	0	0	0
6	0	0	0	0
Total	3,660	2,113.5	3,660	2,113.5

Table 6—Area of timberland by hardwood damage zone and forest type, February 1994 ice storm, northern Mississippi

Damage zone	Timberland	Oak-pine	Oak-hickory	Oak-gum-cypress	Elm-ash-cottonwood
	Thousand acres				
1	1,197.0	217.3	579.9	102.6	24.4
2	889.0	130.2	432.1	186.7	0
3	27.5	0	18.3	0	0
4	0	0	0	0	0
5	0	0	0	0	0
6	0	0	0	0	0
Total	2,113.5	347.5	1,030.3	289.3	24.4

Table 7—Area of timberland by pine damage zone and forest type, February 1994, ice storm, northern Mississippi

Damage zone	Timberland	Loblolly-shortleaf: Planted	Loblolly-shortleaf: Natural	Oak-pine
	Thousand acres			
1	1,008.0	157.3	83.1	165.1
2	1,059.8	113.5	58.8	182.5
3	36.5	9.2	0	0
4	9.2	0	0	0
5	0	0	0	0
6	0	0	0	0
Total	2,113.5	280.0	141.9	347.6

Table 8—Net volume of live trees by species group and damage zone before and after the February 1994 ice storm, northern Mississippi

Damage zone	Percent damage	Hardwoods		Softwoods	
		Prestorm	Poststorm	Prestorm	Poststorm
		Million cubic feet			
1	8.33	656.5	601.8	420.3	385.3
2	25.00	595.0	446.2	304.9	228.7
3	41.67	9.7	5.7	0.2	0.1
4	58.33	[a]	[a]	0	0
5	75.00	0	0	0	0
6	91.67	0	0	0	0
Total		1,261.2	1,053.7	725.4	614.1
Net volume loss			207.5		111.3

[a] Indeterminable.

Net volume of live trees in the FIA survey database refers to the cubic-foot volume of trees with a minimum diameter at breast height of 5.0 inches and a minimum top diameter of 4.0 inches diameter outside bark.

Volume loss due to stem breakage and mortality of the hardwood component was 16.5 percent of the prestorm net live-tree volume (table 8). Similarly, softwoods lost 15.4 percent of volume. However, the total hardwood volume loss (208 million cubic feet) was nearly twice that of softwoods (111 million cubic feet). Timberland basal-area breakdowns may be misleading when making damage-loss comparisons. Before the ice storm, approximately 40 percent of the live-tree volume was in softwoods, whereas only 30 percent of the basal area was in softwoods.

Discussion

Slightly more than 1 percent of the timberland area sustained heavy mortality of trees. The heaviest concentration of probable mortality (about 46,000 acres) showed volume loss at about 4 million cubic feet of timber. This pales in comparison to the widespread damage across the lightly affected areas (zones 1 and 2). Although only 16 percent of the volume in zones 1 and 2 was lost, the storm's widespread effect was 77 times the volume loss within the small timberland area of zones 3 and 4.

Within moderate damage areas (zones 3 and 4), roughly 40 percent of the volume was affected. Overall, 16 percent of the live-tree volume damage was stem breakage and downed trees. Softwoods other than pine and cypress, which constituted less than 3 percent of the total volume, were grouped within and treated as pine for damage assessment.

Over 99 percent of the area showed some form of damage to canopy or bole. Twelve percent of the records were interpreted as showing no damage to the volume component, while less than 2 percent showed no damage to the canopy. Only five records from the video imagery showed no damage to bole or canopy. These sample location records represent the extreme edge of the study area or the premerchantable hardwood component where no damage was evident. Only 18 records showed pine and hardwood components to be in a premerchantable stage; and 12 records predominantly showed pine. All of the latter showed considerable damage to the pine canopy but light or no damage to the stems, while the hardwood damage was moderate or nonexistent.

Timberland area and prestorm hardwood volume were slightly higher in hardwood zone 1 than in zone 2. At 25 percent, the midpoint damage value in zone 2 was triple what it was in zone 1 (8.33 percent), as was the hardwood volume damage. For softwoods, zones 1 and 2 were equal in timberland area and zone 1 contained more prestorm softwood volume. Calculations show that zone 2 had twice the damage of zone 1.

Canopy damage is not very serious when ice causes only temporary damage, e.g., defoliation and the pruning of some limbs. However, some of the more serious crown damage affects tree form by breaking tops and stripping some large forks and limbs from the bole. This also leads to immeasurable volume damage in merchantable tops. In addition to its effect on timber volume, the storm's more serious damage to tree form will affect future volume grade due to growth loss, potential pathogens, and insects.

Species composition and terrain play minor roles in timber damage. A small amount of hardwood volume damage results from ice-laden pines falling against hardwoods, which may break the main bole or, in saturated soils, uproot them. Other hardwood volume damage occurs in bottomland soils, which become saturated as rain precedes the Arctic cold front and its freezing wind.

Where there are gaps in the canopy, hardwood and softwood stems appear susceptible to windthrow and breakage in very wet areas and along streams and ditches. Trees adjacent to open areas are especially susceptible because there is no surrounding canopy to protect crowns. As a result, we documented the edge-effect variable during our earliest interpretation process. An edge is where timberland meets open lands, e.g., pasture and agricultural land, rights-of-way for roads and transmission lines, and water bodies.

Although edge seemed problematic in our design of a damage equation, less than 50 percent of the video sample locations contained any type of edge. Less than 15 percent of the samples showed ice damage resulting from any type of edge effect. Of the records that showed such damage, edge appeared not to be the major factor contributing to bole loss and mortality.

The concept of edge effect also seemed inappropriate when we determined the prevalence of the domino effect. Some stands, especially those of evergreen softwoods like pine and redcedar, displayed appearances of wind shear, as well as the appearance of trees fallen like dominoes. Adjacent timber of the same forest type and stand-size class appeared unaffected by bole mortality and exhibited only ice-laden canopy damage.

Conclusion

Following a severe ice storm in 1994, GPS and airborne videography techniques provided a GIS-mapped assessment of damage to forest resources in northern Mississippi. The GIS map links video interpretation schemes with data from the recently completed FIA field survey to provide estimates of timber volume losses. During times of limited fiscal resources, this technique can reduce the need for extensive ground analysis of damaged areas.

Natural catastrophic damage can be characterized spatially through interpretation of airborne videography transects. Global Positioning System coordinates encoded onto video images facilitated development of GIS products for the impacted area. Together with existing data bases of forest resources, GIS products enabled analysts to develop estimates of timber damage soon after the storm event.

A relatively small portion of the study area received concentrated heavy damage to the forest resources, i.e., only 3 percent of basal area before the ice storm. Yet the much broader area that sustained light damage actually contained 99 percent of the damage resulting from mortality and volume loss.

We need to develop techniques for determining volume loss from merchantable top breakage; and we should find a means, likewise, of estimating current and future loss to damaged premerchantable timber.

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During February 8–11, 1994, a severe winter storm moved from Texas and Oklahoma to the mid-Atlantic depositing in northern Mississippi a major ice accumulation of 3 to 6 inches. An assessment of forest resource damage was initiated immediately after the storm by performing an airborne video mission to acquire aerial imagery linked to global positioning coordinates. Interpretation of the aerial video imagery generated data that were used to map zones of similar damage severity. The Geographic Information System map data were linked with recent State forest resource inventory data to provide estimates of forest resource damage. There were 2.1 million acres of forest land within the 3.7-million-acre study area in northeast Mississippi. Less than 1 percent of the forest land remained untouched by some degree of damage. Net loss to live-tree volume, due to probable mortality, amounted to 16.5 percent of hardwoods and 15.3 percent of softwoods. The majority of volume loss occurred in areas that received about 25 percent mortality to the forest resource.

Keywords: Aerial reconnaissance, airborne video system, GIS, GPS, ice storm damage, isozone, Mississippi.

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