FOREST INVENTORY, CATASTROPHIC EVENTS AND HISTORIC GEOSPATIAL ASSESSMENTS IN THE SOUTH

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ABSTRACT

Catastrophic events are a regular occurrence of disturbance to forestland in the Southern United States. Each major event affects the integrity of the forest inventory database developed and maintained by the Forest Inventory & Analysis Research Work Unit of the U.S. Department of Agriculture, Forest Service. Some of these major disturbances through the years have received an inventory assessment to determine the approximate amount of damage to both the volume and area of the forest resource. These events include ice storms and different intensities of hurricanes. General maps of these events provide levels of potential storm damage to the resource. This paper presents an overview of the history of these mapped assessments and the different methods and levels of effort involved. The rapid assessments occurred within days or weeks after the storm, while the more comprehensive assessments began several months after the storm event and after timber salvage operations were coming to an end.

INTRODUCTION

The United States Department of Agriculture has performed statewide forest inventories since the 1930s through the Forest Service national Forest Inventory and Analysis program (FIA) and associated research units and State partners. In the past, performing catastrophic forest damage assessments hinged upon requests from interested parties and whether expense, effort, or safety reasons allowed the work to take place. As expense and quality of modern technology improved through time, it has become easier to perform these operations in a safe and efficient manner. New methods have been developed over the years to supplement field inventories, with these having been replaced by even newer techniques and different technological advancements. Several large-scale catastrophic events have affected the integrity of the forest inventory database through the years. Starting in 1969 with Hurricane Camille, FIA has been involved with other agencies in responding to these disasters. Depending upon the extent designated as the storm area, each event produced damage equivalent to 1- to 3-years worth of growth and up to 5 or more years within the heaviest impacted area.

State forestry agencies and other Forest Service offices have flown aerial reconnaissance missions for each of these storm events and many other storms, in which FIA was not involved. Methods for determining extent of each storm ranged from delineating a simple area across a county-line map to collecting aerial imagery from the aircraft or performing field-visit assessments. A favored method by some States, after developing an aerial reconnaissance map, has been to generate sketch maps from the aircraft. This technique has improved over time, progressing from paper maps to direct editing of digital sketch maps on a laptop computer in the aircraft. A reconnaissance map provides the general area to be flown along with storm intensity patterns. The sketch mapping or aerial imagery acquisition can then be flown perpendicular to the progression of the storm.

Where sketch mapping techniques provide specific pockets of heavy to moderate damage to the forest resource on a map, the FIA mapping techniques have generally provided large polygons on the map showing progression of the storm damage in more general terms. These large polygons have the purpose of applying expected mortality to the FIA plot or county data throughout the broad-scale area associated with these polygons. In recent years, forestry managers and policy makers are demanding more detailed map products. Some major events have received change detection assessments, in the form of research projects, using satellite data (Ramsey, *et al.* 1998). The national forest inventory program is building upon this research knowledge and currently looking at methods of rapid response using satellite imagery for performing future forest damage assessments (Nielsen, *et al*.).

CATASTROPIC STORMS OF THE PAST

Hurricane Camille, Southern Mississippi-1969

The Southern Forest Experiment Station combined the efforts of its forest inventory unit with the Forest Service, Division of Forest Pest Control in cooperation with the State of Mississippi to survey the 15 counties hardest hit by Hurricane Camille in Mississippi. Forest damage was more widespread than the area surveyed, but on-the-ground field measurements focused on the most severely-damaged area. And although the Delta and Florida parishes of Louisiana were heavily affected, along with portions of Alabama, the survey was limited to Mississippi.

Hurricane Camille struck the Gulf Coast at Waveland, Mississippi shortly before midnight on August 17, 1969. At that time, this Category 5 hurricane (Saffir-Simpson Hurricane Intensity Scale) was the worst storm ever to hit the continental United States, with wind speeds approaching 190 to 200 miles per hour and tidal surge as high as 22 feet. The Alexandria Office of Forest Pest Control flew an aerial reconnaissance mission and provided a map for FIA planning and field inventory efforts (Figure 1, Van Hooser and Hedlund 1969). Independently, Forest Pest Control produced a more detailed map (Figure 2, Terry, *et al*. 1969) by sketch-mapping fifty percent of the area along flight lines perpendicular to the path of the storm during the dates of August 20-26.

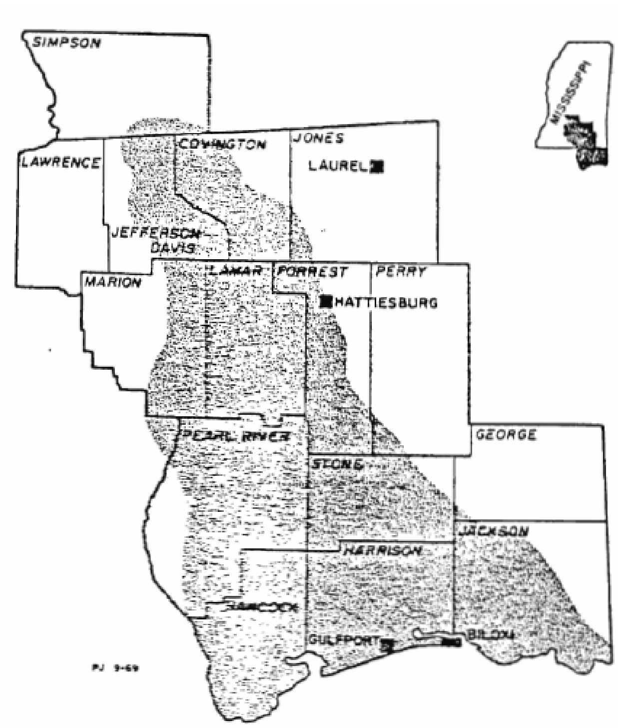

Figure 1. Rough map of major timber damage area associated with Hurricane Camille.

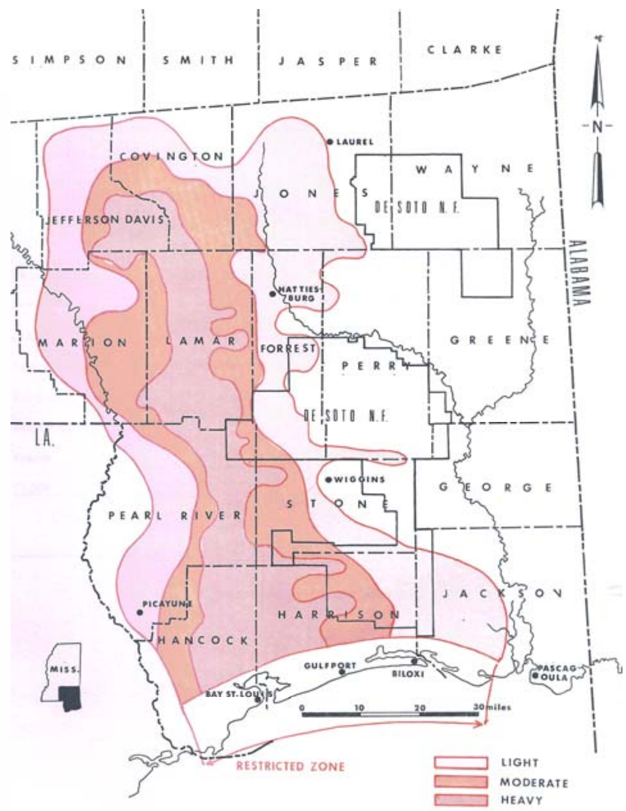

Figure 2. Aerial sketch-map from visual observations.

Within the fourteen-county, 3.8-million-acre area surveyed, the Forest Pest Office determined that roughly 1.9 million acres of forestland sustained visual damage, with 440,000 acres heavy damage and 470,000 acres of moderate damage. For this assessment, light damage considered less than 1/3 of trees as damaged, and heavy damage was greater than 2/3 of trees damaged. No ground verifications were performed for development of this assessment and map. Visual perception from the aircraft was that hardwood forests sustained heavier damage than pine forests in the area, possibly due to wind-stripped, defoliated canopies. Also, it was noted that open-grown longleaf pine stands and young plantations received more damage than other pine stands.

The forest field survey was performed September 3-17 within a fifteen-county area. The field assessment focused on volume rather than acreage, and data were collected on a grid of plots spaced at 4-mile intervals. About 290 million cubic feet of timber was destroyed, representing about ten percent of the inventory in the fifteen-county area. With the exception of the two heaviest-impacted counties, softwoods sustained a slightly higher overall proportion of volume damage than hardwoods (11.6% vs. 8.3%). The four counties receiving the most damage lost from 21 to 37 percent of the original timber volume.

Hurricane Hugo, South Carolina-1989

Hurricane Hugo made landfall near Charleston, South Carolina on September 21, 1989 as a Category 4 hurricane with wind speeds of 135 miles per hour. The South Carolina Forestry Commission performed aerial reconnaissance for immediate and future planning purposes. Afterwards, the Forestry Commission requested that FIA perform a comprehensive field survey within the 23 counties in the State receiving the heaviest damage. Comprehensive field inventory data were needed for developing future forest resource management plans and immediate fire mitigation provisions. During the ensuing months, plans were developed and funding established for collecting the field data. The Hugo inventory assessment was markedly different from the Camille assessment in that permanent FIA plots from the 1986 State inventory were remeasured. Further, the Camille assessment occurred immediately following the storm, before salvage operations were in full force. The Hugo field inventory took place from February through June of 1990, five to nine months after the catastrophic storm and after most major salvage operations had ceased. General forest plot locations and field inventory information were used to develop a Thiessen polygon map representing damaged forest areas for the 23-county area (Figure 3, Sheffield and Thompson 1992). Forest damage occurred within unshaded areas of the map, but was not exhibited within the plot for that location because the plot was either an undamaged forest plot or simply a nonforest plot containing no forest data. Likewise, shaded areas contain some amount of nonforest land, and not all forest in the local area sustained similar amounts of damage as that exhibited by the forest plot representing that portion of the Thiessen polygon map.

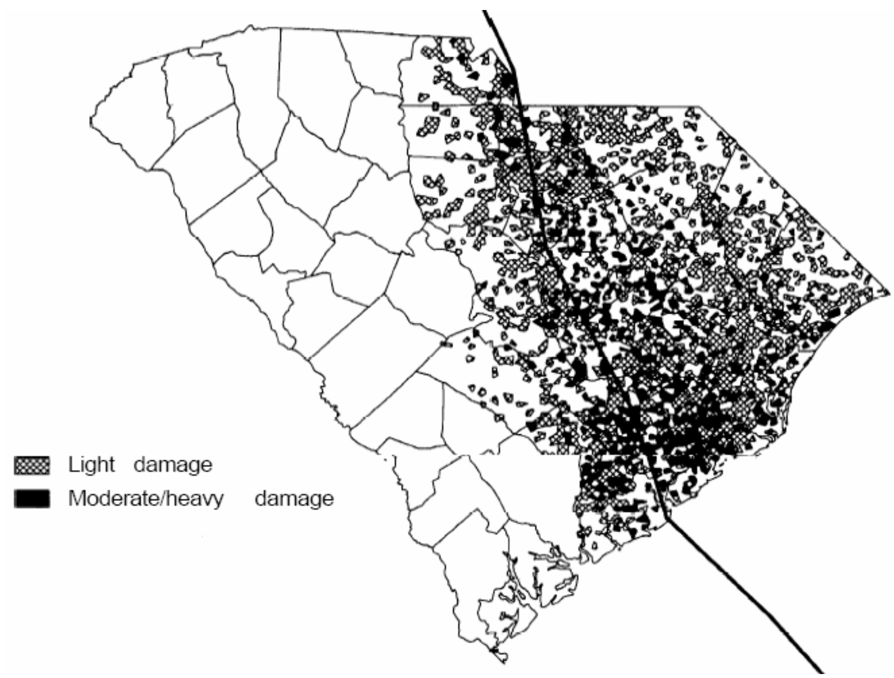

Figure 3. General distribution of forest damage in select counties and track of Hurricane Hugo.

The 23 counties surveyed contained 6.5 million acres of timberland (6.6 million acres forestland) within the 10.5-million acre area. Approximately 4.5 million acres of timberland were damaged by the storm, with about 1.3 million acres in the moderate to heavy category. In comparison, the Camille assessment area was constrained to only 3.8 million acres containing 1.9 million acres of forestland and 0.9 million acres deemed moderate to heavy damage. The overall assessment suggested that lowland hardwoods sustained a greater impact (77% damage) throughout the landscape than pines (62-68% of acreage damaged). Lowland hardwoods are more closely associated with the coastal area, which received the strongest hurricane-force winds. In comparison, upland hardwoods sustained 64% area damage.

About 21% of the softwood volume was killed by the storm. For hardwoods, the mortality was estimated at 6%, but another 12% was in a high-risk category of live trees susceptible to immediate mortality due to blow down and other severe damage. Comparatively, softwood pre-storm volume was 4.8 billion cubic feet and hardwood volume was 5.1 billion cubic feet. Cypress received about a 3% loss in volume. Overall, about 1.3 billion cubic feet of timber was included as killed or salvaged.

Hurricane Andrew, Southern Louisiana-1992

Hurricane Andrew traveled across southern Florida and headed toward the Gulf Coast, making landfall a second time during the night of August 25, 1992 near Franklin, Louisiana. After seeing the ferocity of the storm in Florida, FIA personnel at the Southern Forest Experiment Station prepared for a major landfall occurrence along the Gulf Coast, making plans to acquire airborne videography and simultaneously collect georeferenced information on the ground via Global Positioning System (GPS) receivers. The aerial mission was flown August 29-31, with flight lines oriented perpendicular to the path of the storm. An aerial reconnaissance map had been developed by the Louisiana Office of Forestry for planning the image acquisition area. Cloud-cover situations played an important factor in development and use of airborne videography for such similar missions where aerial photography is problematic due to haze and cloud shadow effects. The Global Positioning Satellite System was also a new technological development, which allowed for immediate georeferencing of the video imagery in the aircraft. Snapshot frames were acquired from the video imagery for visual interpretation on computers. GPS coordinates were used for placing interpreted forest damage attributes into a geographic information system as data points. A damage class polygon layer was produced from the point data (Figure 4, Jacobs and Eggen-McIntosh 1993). In turn, this polygon layer associated the damage classes with FIA plots within each polygon and generated a timber damage report by damage class and species group.

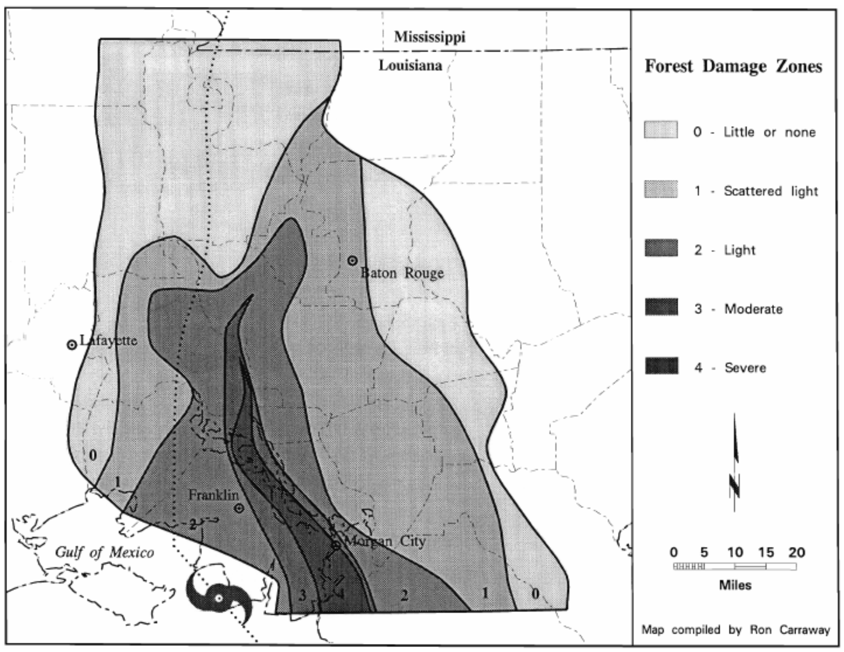

Figure 4. Timber volume damage map generated using airborne video, GPS and GIS technology for the Hurricane Andrew assessment.

The Hurricane Andrew forest assessment area included portions of 18 parishes encompassing 4.2 million acres containing 1.8 million acres of timberland. Approximately 1.1 million acres of this forestland received some type of volume damage, but only about 127,000 acres of timberland fell within the heavy and moderate damage areas of the map. And, not all of that timberland was heavily damaged. The predominant forestland in this area is oak-gum-cypress forest type and mostly located within the Atchafalaya River Basin of Southern Louisiana. Any pine forestland was located in the extreme northern portions of the assessment area or beyond. Damage categories were an attempt to build upon past knowledge of FIA hurricane damage assessment and included the three main classes of heavy, moderate, and light, with the final map portraying a scattered light category where slight damage occurred throughout fragmented forest patches. Heavy represented greater than 66% volume loss. The lower category representing less than 33% damage was split evenly due to its massive size in area.

About 10 percent of the standing volume within the assessment area received a probable mortality blow by Andrew. Hardwoods received about 12% loss in volume due to mortality and cypress about a 7% reduction. Within the heavy and moderate areas, volume impact was about 66%. Approximately 380 million cubic feet of timber was considered as mortality due to Andrew.

East-wide Ice Storm, Northern Mississippi-1994

A major ice storm passed through north Mississippi February 8-11, 1994. After the Mississippi Forestry Commission flew an aerial reconnaissance mission and mapped the damaged area, FIA was asked to perform an assessment due to the widespread extent and massive damage viewed from the air. The State inventory had recently been completed and the Commission felt that the storm damage greatly affected the integrity of the volume numbers in that report. This storm event developed in the Southern Plains and progressed eastward through Washington, D.C. inflicting the worst damage to the forest resource at the northern fringe of the southern pine belt in across the South. Ice accumulations were as great as 3-6 inches throughout much of the north Mississippi assessment area. FIA proceeded with plans to perform similar assessment procedures as were developed during the Hurricane Andrew assessment. Flight line transects were designated perpendicular to the bands of storm severity depicted on the Forestry Commission's reconnaissance map.

The 3.7-million-acre assessment area contained 2.1 million acres of timberland (Figure 5, Jacobs 2000). Less than 1 percent of the forest area remained unscathed by the ice-accumulation damage to canopy, branches and boles. There existed isolated patches of severe damage greater than 66% throughout the assessment area, as many forestland owners will attest, but these patches were not in broad enough aggregate form to depict on the map. The result was that only 3% of the forest resource fell within polygons on the map having greater than 33% damage.

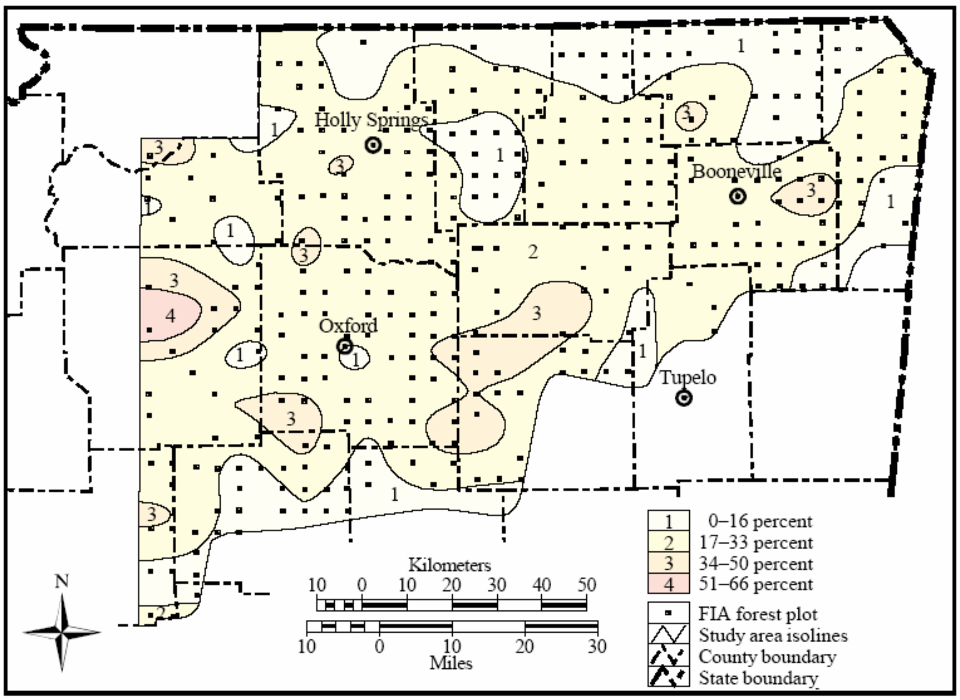

Figure 5. Volume damage associated with the portion of the 1994 east-wide ice storm in northeast Mississippi.

Mortality volume losses were estimated at 15.3% for softwoods (111 million cubic feet) and 16.5% for hardwoods (208 million cubic feet). Approximately three-fourths of the forestland in this area was hardwood forest. The softwoods were predominantly loblolly and shortleaf pine and many pines were bent, leaning, or slightly root sprung due their status as evergreens. Since this assessment focused on downed and broken stems, it was expected that many of the leaning pines would be removed during salvage operations or later succumb to mortality. This one aspect could have increased the softwood damage component considerably.

HURRICANE SEASONS 2004

After a reprieve of several years and an occasional discussion whether to perform a catastrophic event damage assessment, FIA received a request soon after Hurricane Charley hit the west coast of Florida. Charley, the strongest hurricane to hit Florida since Hurricane Andrew, made landfall as a Category 4 hurricane on Friday, August 13, 2004 with winds estimated at 145 miles per hour. As plans were being developed, expediency not at the forefront, along came Hurricane Frances on September 4, making landfall on the east coast of Florida as a Category 2 hurricane, with wind speeds clocked at 105 miles per hour, and working its way across and up the west coast of Florida through September 6. FIA immediately received a second request from the Florida Division of Forestry for a forest damage assessment related to both storms. By September 10, a rapid assessment had been performed on Frances and deliverables sent to the Division of Forestry along with a letter explaining change in procedures due to the urgency of a rapid response. Work immediately began on overlooked Charley, a stronger storm than Frances, yet more narrowly focused and faster moving.

Before the Charley assessment was complete, Hurricane Ivan made landfall near Gulf Shores, Alabama in the wee hours of September 15, 2004 with sustained winds of 130 miles per hour, a maximum Category 3 hurricane. Over the Gulf, Ivan had sustained itself, alternating as a Category 5 and 4, but was immediately downgraded to Category 3 at the point of landfall. Since Ivan was a slower-moving storm and more widespread than Charley, it was assumed to have delivered a far greater amount of damage to the forest resource and throughout many more acres of forestland. Urgency moved Ivan ahead of Charley for a rapid assessment response. Deliverables were ready by September 23 and presented to forestry professionals in Florida, Alabama and interested U.S. Forest Service entities. Due to the urgency of the situation, a rough draft of Charley was also included. The damage estimates and maps for the three hurricanes were aggregated into a report and presented to policy makers at the national and state level, for providing disaster assistance. Forestry professionals in the Forest Service Southern Region and state offices, who are responsible for fire management and forest landowner assistance, use the damage estimates and maps for planning and budgeting purposes.

Jeanne made landfall on the east coast of Florida, near Stuart, as a Category 3 hurricane shortly after midnight on September 26 with sustained winds of 120 miles per hour. Confusion had set in by this point, and damage extent was difficult to ascertain for Jeanne, as it followed closely along the same path of Frances, and passed over forest resource areas recently damaged by the three other hurricanes. The curious aspect was to determine just how much damage could occur to the forest resource that had already been devastated by the other hurricanes. This notion had already been grappled with after Frances crossed the path of Charley, perpendicular through central Florida, and had traversed into the Panhandle where Ivan landed. Estimated potential volume damage was applied to the forest resource assumed to be still standing after each previous storm. The damage assessment for Jeanne was in final form by October 5.

The 2004 hurricane was unprecedented due to the number of major hurricanes hitting the coast of Florida in a single season. These rapid assessments present "potential" damage to the forest resource, due to the urgency of the situation. Only field measurements can provide the best qualified answer, and these will come in the form of annual sub cycles of field data collected each year through normal field data collection by FIA.

Current and future volume loss, due to form damage and branch breakage of standing live trees, was not a part of these rapid response estimates. However, historical field assessments generally place this impacted volume estimate at one-third to two-thirds of the estimated volume left standing after mortality has been subtracted from the total inventory. This additive amount provides an estimate of the damaged timber that might be removed if resources could be returned to a healthy forest condition within the two or three most heavily impacted damage zones in the central portion of the storm damage area.

Rapid Response Procedures

For the hurricanes of 2004, with the exception of Charley, weather data products were gathered immediately after each storm had been downgraded to below hurricane status. Internet searches provided the source data products, which included such items as the eye path of the storm and maps of wind speed, wind patterns, rainfall accumulation, and tidal surge areas. These mapped data products were generally provided by the National Weather Service and the National Hurricane Center during progression of each storm. This allowed FIA to pull the latest forest inventory data for the area currently being impacted during the storm. This data would be immediately available for applying expected damage values from the final rendition of the forest damage map.

Modeled wind swaths and accumulated rainfall maps were merged to generate polygon maps portraying categories of potential damage to forest resources. Particular importance was placed on the eye-track of the storm, as most forest resource damage occurs immediately adjacent to the windward side of the path. Along the Atlantic and Gulf coasts, this is to the right of the eye path.

When possible, maps provided by the State forestry agencies were used to either help in the development of the potential damage map or for verification after the map was in final form and reports had already been submitted. An example is where the Florida Division of Forestry flew aerial photography for Hurricane Charley August 18-23 and provided the flight line map to FIA on September 10. This provided verification of the heaviest damage area and a chance to modify polygons for that map, since that report had yet to be submitted. The Alabama Forestry Commission provided an aerial reconnaissance map of Hurricane Ivan at the time FIA completed the final report. It provided verification that the final map was fairly accurate and no adjustments were made.

After a map was in final form, each severity-level polygon was cross referenced with historical forest damage assessments in order to determine an associated potential estimate of the downed timber. Wind speed within the hurricane category level of each storm was also used to decide whether a higher or lower percent damage value should be associated with the current storm. Frances was especially problematic since past assessments had not included a Category 2 hurricane. In an attempt to follow tradition, each mapped damage zone tended to represent severe, moderate, light, and scattered light categories; labeled 4, 3, 2, and 1 respectively. Percent damage values associated with damage zones were: Zone 1) 0-1%; 2) 1-5%; 3) 5-20%; and 4) 20-50%.

Maps and Associated Forest Resource Damages

Forest inventory mortality damage associated with the four hurricanes totaled to a potential 2 billion cubic feet of timber, half of this due to Hurricane Ivan in Alabama alone. Associated potential damages (million cubic feet) for each hurricane are: Charley, 133 mcf; Frances, 145 mcf; Ivan, 1,320 mcf; and Jeanne, 381 mcf. An attempt at determining damaged forestland area was not performed. The current method of forest inventory by the FIA program is to visit twenty percent of inventory plots each year on a rotating sub cycle basis. Current and future inventory data might answer whether these potential damage mortality estimates were correct.

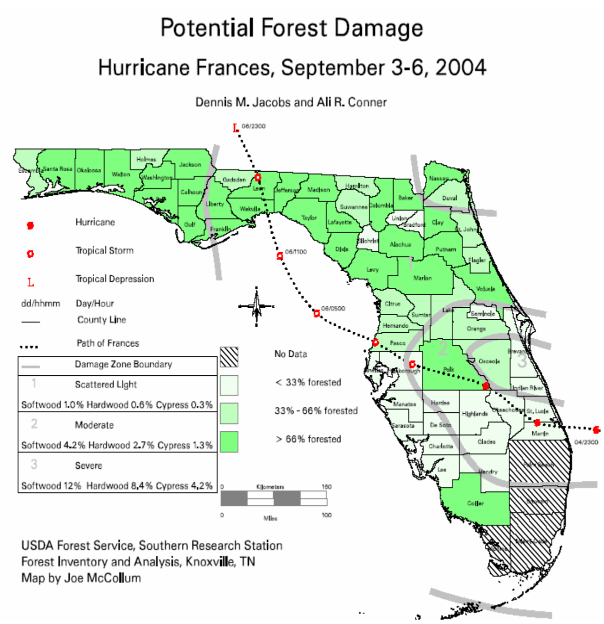

Figure 6. Potential forest damage map presented for Hurricane Frances.

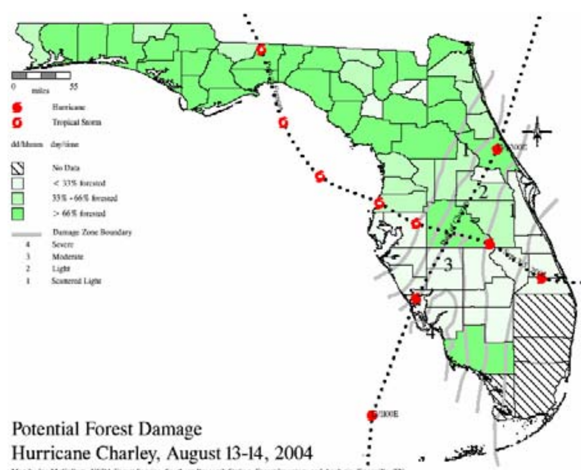

Figure 7. Potential forest damage map presented for Hurricane Charley.

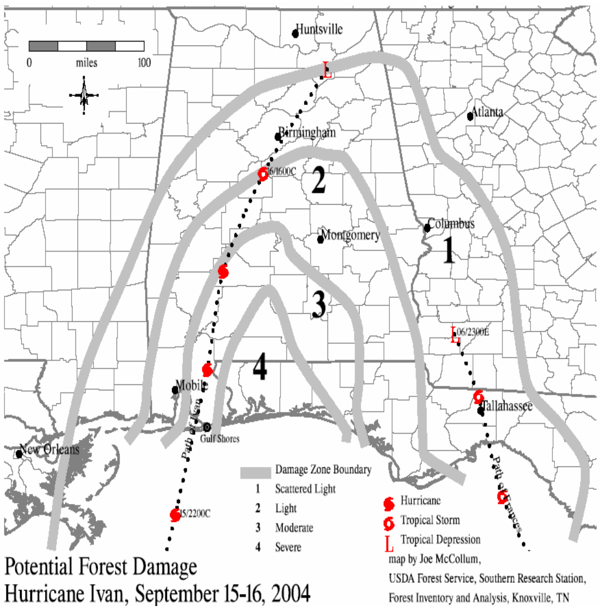

Figure 8. Potential forest damage map presented for Hurricane Ivan.

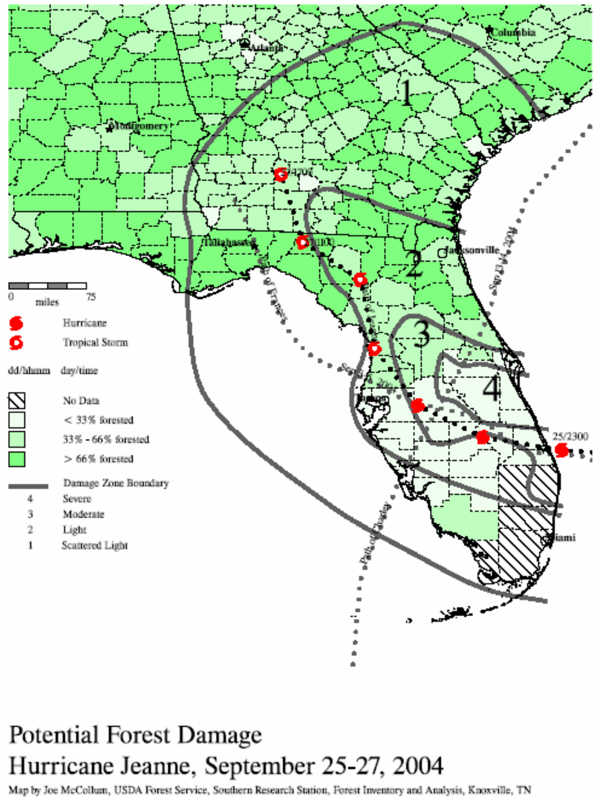

Figure 9. Potential forest damage map presented for Hurricane Jeanne.

HURRICANE SEASON 2005

Katrina: Louisiana, Mississippi, Alabama

After crossing the southern tip of Florida as a Category 1 hurricane, Katrina traveled through the Gulf of Mexico, gaining strength to a strong Category 5 hurricane as it turned north toward the Gulf Coast. Before it made landfall, and before the phones starting ringing with requests coming in, data were being gathered to perform the forest damage assessment. The forward winds of the Category 5 hurricane were battering the southeast coast of Louisiana, before being downgraded to Category 4 as it made landfall a second time near Buras, Louisiana with wind speeds over 140 miles per hour. Later that day, Katrina made landfall a third time at the Mississippi/Louisiana state line on August 29, 2005. By the time the eye of the storm arrived in Mississippi, Katrina had been downgraded to a strong Category 3, with wind speeds of approximately 125 miles per hour.

Procedures developed during the 2004 hurricane season were implemented for this forest damage assessment. Wind speed charts and maps were monitored and gathered from the National Hurricane Center, as well as accumulated rainfall from the National Weather Service. Local Doppler sites that were still operational were also monitored for verification of heavy rainfall associated with the current storm activity. A forest damage map (Figure 10) had been assembled by Friday, September 2 and preliminary volume damages were presented on September 6. Following polishing and corrections, the final draft was ready by September 13.

A county choropleth map provided by the Mississippi Forestry Commission showed enough similarity that the FIA map was left unchanged. However, percent damages presented on the map generated an upward adjustment in the FIA damage numbers. After discussions with the Alabama Forestry Commission, the decision was that far less damage occurred in their state due to the amount of devastation still evident from Hurricane Ivan a year earlier. Trees susceptible to wind throw and breakage had received stronger hurricane force winds during Ivan (Figure 11) and far less damage was inflicted by Katrina. The Louisiana Office of Forestry was able to get a plane in the air a few days after the storm and determined that there was greater damage farther inland than expected or shown on the map. An overlooked aspect of the hurricane was how the storm's track would unite with hurricane force winds, from the windward side of the storm, and reach farther inland over the open waters of Lakes Borgne and Pontchartrain.

Comparing the 12 to 15 heavily-impacted counties of Hurricane Camille, Katrina inflicted severe damage upon 13 counties/parishes, and included another 16 counties/parishes of scattered moderate damage. This is not necessarily reflected in the map (Figure 10). Three heavily-impacted parishes were not part of the FIA inventory in 1969, and were most likely impacted by Camille. Also compared with Camille's 910,000 acres of moderate/severe associated with the central focus of the storm, the larger area of Katrina suggested that about 2 million acres of timberland received some form of severe damage to the forest resource. Potential volume mortality associated with this assessment amounted to approximately 1.7 billion cubic feet (Table 1). Another 2.5 billion cubic feet of standing live timber was put at risk of succumbing to mortality or sustaining expected loss of volume to the stem due to bole damage or branch breakage. Roughly 5 million acres of timberland was affected to some extent by Hurricane Katrina.

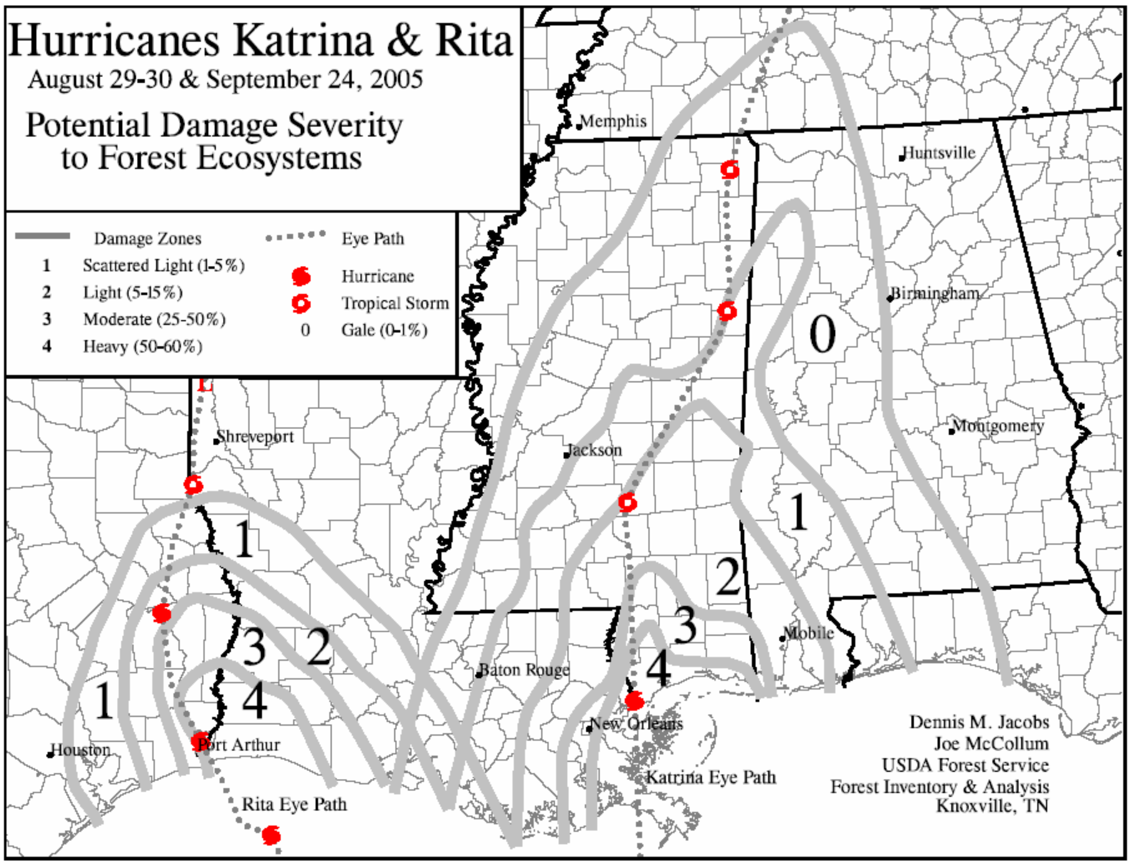

Figure 10. Hurricanes Katrina and Rita combined into a singular map to show similarities and differences.

Rita: Louisiana, Texas

As September 24, 2005 approached, Hurricane Rita was traveling across the Gulf of Mexico heading for Sabine Pass, Texas. Rita made landfall as a Category 3 hurricane, with sustained winds approaching 120 miles per hour. While watching the approach of the hurricane, FIA was in contact with the Louisiana Office of Forestry and the Texas Forest Service (TFS), making plans for imminent landfall. TFS prepared for a rapid on-the-ground assessment immediately after the storm to enhance the quality of the expected forest damage assessment. After the storm had passed through the area on September 25, all necessary weather data were gathered and a damage map draft was presented that day (Figure 11). Both States performed reconnaissance missions and adjustments were made to the FIA map (Figure 10).

Forest area affected by Rita amounted to approximately 1.4 million acres, with about 600,000 acres considered as imminent mortality. About 800 million cubic feet of timber was damaged by the storm, with another 650 million cubic feet receiving damage affecting the bole and branches and impacting future growth. Since there was little forestland in Cameron Parish, most of the severe damage occurred farther inland, in Texas, immediately adjacent to the windward side of the storm track. Likewise, there was a reduced amount of forest resource damage associated with Rita because it had to track at least twenty miles inland before encountering forestland.

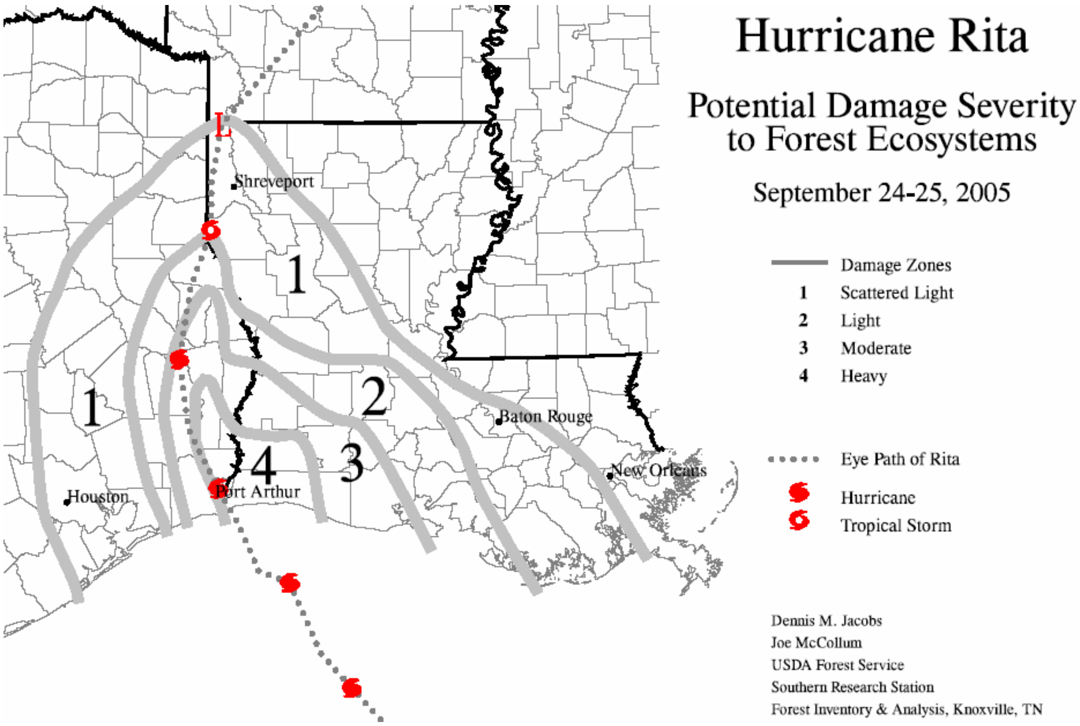

Figure 11. First draft of potential damage by Hurricane Rita following procedures using weather data.

Table 1. Potential Damage Severity to Forest Ecosystems
Hurricane Seasons 2004-05

Hurricane & Category	Volume Loss	Volume at Risk	Volume Affected	Timberland Affected
	million cubic feet			*acres*
Charley / Cat. 4 Aug. 13-14, 2004	133	100	233	-
Frances / Cat. 2 Sep. 3-6, 2004	145	100	245	-
Ivan / Cat. 3 Sep. 15-16, 2004	1,320	1,000	2,320	-
Jeanne / Cat. 3 Sep. 25-27, 2004	380	220	600	-
Year 2004 Total	1,978	1,420	3,398	-
Katrina / Cat. 4/3 Aug. 29-30, 2005	1,740	2,495	4,235	5,000,000
Rita / Cat. 3 Sep. 24-25, 2005	811	647	1,458	1,400,000
Year 2005 Total	2,551	3,142	5,693	6,400,000

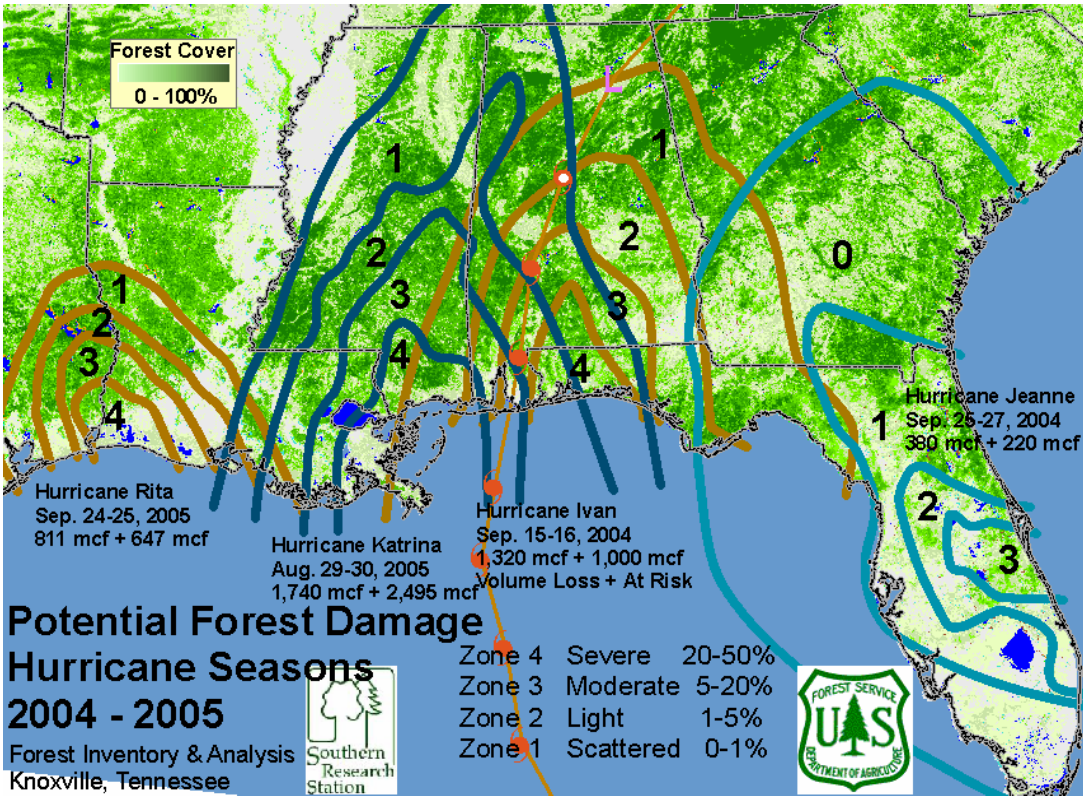

Figure 12. Associated overlaps of the four most recent hurricanes. 'Volume loss' and 'at risk' represent potential mortality and damaged standing live volumes, respectively, in million cubic feet (mcf).

HURRICANE SEASON 2006

There were no catastrophic events worthy of consideration for a forest damage assessment during the 2006 hurricane season. Some hurricanes attained a Category 3 status but either weakened before making landfall, thus inflicting only slight amounts for forest damage or the storm system simply stayed away from the continental U.S.

SUMMARY

Weather data have become almost instantaneously available through the internet in recent years, allowing anyone with access to obtain the data and follow major weather disturbances during and immediately following an event. Rapid response maps will probably continue to be used as the first choice for delineating the area of catastrophic disturbance, selecting satellite imagery, and during the decision process of whether to collect field data or where to focus field data collection efforts. Maps associated with the historical, more comprehensive surveys, focus on where field data collection efforts were concentrated, and don't necessarily reflect the minor scattered damage found beyond the limits of the field inventory. Mapped data for the most recent hurricane seasons include the broader areas of scattered light damage, where pockets of wind shear and tornados affected the forest resource, and beyond the concentrated damage-area where any field inventory efforts take place. Future assessments will build upon satellite imagery classifications and can also employ classification maps of modeled forest biomass for determining area and volume damages (Salajanu, 2006). Forest resource analysts will continue to monitor annual inventory field measurements in order to track remnants of forest resource damage inflicted by hurricanes and other catastrophic events.

REFERENCES

Haymond, J.L., and W.R. Harms, eds. (1996). Hurricane Hugo: South Carolina forest land research and management related to the storm. Gen. Tech. Rep. SRS-5. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 540 p.

Jacobs, D.M. (2000). February 1994 ice storm: forest resource damage assessment in northern Mississippi. Resource Bulletin SRS-54. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 11 p. http://www.srs.fs.usda.gov/pubs/1873

Jacobs D.M., S. Eggen-McIntosh (1994). Forest resource damage assessment of Hurricane Andrew in southern Louisiana using airborne videography. In: *Proceedings of the 14th Biennial Workshop on Color Photography and Videography in Resource Monitoring*, May 24-27, 1993. Logan, UT. Bethesda, MD: American Society for Photogrammetry and Remote Sensing. Pp. 115-124.

Jacobs, D.M., and D.L. Evans (1996). Applications of airborne videography in Forest Inventory and Analysis and in assessing catastrophic events. In: Paivinen R, *et al*., eds. *EFI Proceedings No. 7*, 1996: New Thrusts in Forest Inventory: Proc. of the Subject Group S4.02-00 `Forest Resource Inventory and Monitoring' and Subject Group S4.12-00 `Remote Sensing Technology', Volume I, IUFRO XX World Congress, Aug. 6-12, 1995, Tampere, Finland. Joensuu, Finland: European Forest Institute. Pp. 91-104.

Nielsen, E., K. Megown, D. Jacobs, A. Lister, and M. Hoppus (in press). Rapid assessment of forest hurricane damage using MODIS and meteorological data. In: *Proceedings of the 8th Annual Forest Inventory and Analysis Symposium*, Oct. 16-19, 2006, Monterey, CA. St. Paul, MN: U.S. Department of Agriculture, Forest Service, Northern Research Station.

Ramsey, E.W. III, D.K. Chappell, D.M. Jacobs, S.K. Sapkota, and D.G. Baldwin (1998). Resource management of forested wetlands: Hurricane impact and recovery mapped by combining Landsat TM and NOAA AVHRR data. *Photogrammetric Engineering & Remote Sensing*, 64(7):733-738.

Salajanu, D., and D.M. Jacobs (2006). The effect of using complete and partial forested FIA plot data on biomass and forested area classifications from MODIS satellite data. In: *Proceedings: American Society for Photogrammetry and Remote Sensing 2006 Annual Conference*, May 1-6, 2006. Reno, NV. Bethesda, MD: American Society of Photogrammetry & Remote Sensing.

Sheffield, R.M., and M.T. Thompson (1992). Hurricane Hugo: effects on South Carolina's forest resource. Res. Pap. SE-284. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 51 p. http://www.srs.fs.usda.gov/pubs/1892

Terry, J.R., N.A. Overgaard, and W.M. Ciesla (1969). Survey of damage to forested lands caused by Hurricane Camille in Mississippi. Rpt. No. 70-2-18, September 1969. Alexandria, LA: U.S. Department of Agriculture, Forest Service, Southern Area, Division of Forest Pest Control. 7 p.

Van Hooser, D.D., and A. Hedlund (1969). Timber damaged by Hurricane Camille in Mississippi. Research Note SO-96. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 5 p.