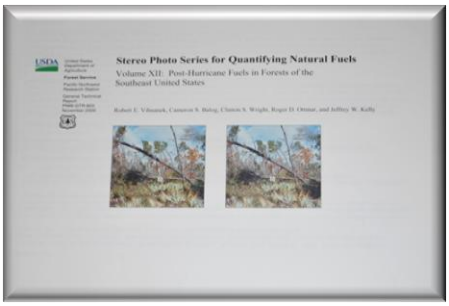
STEREO PHOTO SERIES FOR QUANTIFYING NATURAL FUELS:

Post-Hurricane Fuels in Forests of the Southeast United States



Project Title: Photo Series for Estimating Post-Hurricane Fuels in Forest Types of the Southeast United States

Final Report: JFSP Project Number 06-1-1-11

Project Website: http://www.fs.fed.us/pnw/fera/research/fuels/photo_series/index.shtml

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I. ABSTRACT

The natural fuels stereo photo series is a collection of geo-referenced data and photographs that display a range of natural conditions, fuel loadings, and other fuelbed characteristics in a wide variety of forest-, woodland-, shrub-, and grass-dominated ecosystem types. The photo series are useful tools for quickly and inexpensively evaluating vegetation and fuel conditions in the field. This report describes the development and completion of a single volume Natural Fuels Photo Series that covers a range of post-hurricane fuels in forest types of the southeastern United States. The volume is divided into two series, Gulf Coast dominated by mixed forest species and Atlantic Coast dominated by a heavy shrub understory. The Gulf Coast series contains 13 sites and the Atlantic Coast series contains 7 sites. The printed photo series is available free of charge from the U.S. Forest Service Pacific Northwest Research Station. The photos and data will be available in the Digital Photo Series located at: http://depts.washington.edu/nwfire/dps/.

II. BACKGROUND AND PURPOSE

Photo series provide a quick and easy means for quantifying and describing existing fuel properties often reducing the field time over other inventory methods time by 80 percent. Federal, state, and private fuel and fire managers use the Natural Fuels Photo Series to assist them to quantify fuelbeds for assessing fire severity, fuel treatment effectiveness, carbon stores, air pollutant emissions, and other effects of fire.

There have been many photo series published during the past 30 years (Maxwell and Ward 1976, 1980; Fischer 1981; Blonski and Schramel 1981; Ottmar and Hardy 1989, Ottmar and Vihnanek 1998, 1999, 2000, 2002; Ottmar et al. 1990, 1998, 2000a, 2000b, 2002, 2003, 2004, 2006, 2007a, 2007b;Vihnanek et al. 2009, Wright et al, 2002), many of which were supported by the Joint Fire Science Program (JFSP 98-1-1-05; JFSP 01-1-7-02; JFSP 03-3-3-46). Of all the photo series in existence, there was only one post-hurricane fuels photo series (Wade et al. 1993). This photo series presented a single photograph and fuel loading data for nine 2-acre blocks on the Francis Marion National Forest that were wind damaged by the 1983 hurricane Hugo. However, the series did not capture the range of loadings seen in other sites catastrophically affected by hurricanes in forests across the southeastern United States.

During the summers of 2004, 2005, and 2008 several strong hurricanes affected southern states causing wind damage to thousands of acres of Federal, State and private forests, resulting in very large accumulations of downed woody debris. Much of this debris was in the wildland-urban interface, creating the potential for catastrophic loss of property and life if a wildfire were to occur. Because fuelbed characteristics are critical for assessing appropriate fuel treatment strategies to reduce fire hazard, local disaster managers, incident command teams, and fire and fuel specialists requested that a fuels photo series be developed to allow quick and easy assessment of fuel loading and depth for hazardous fuel treatment planning. The photo series will also enable assessments to be completed quickly and easily in other areas of the United States where wind damaged forests occur.

The specific objective of this research was to compile a sequence of single and stereo photographs with accompanying vegetation and fuels characterization data that provided a quick and easy means for quantifying and describing existing fuel properties for a range of stand and damage conditions in pine and hardwood forests affected by hurricanes in the southern United States. There were four major goals for this project these included:

1. Assess the literature and the needs of the managers to define the southern pine and hardwood fuelbed types impacted by the hurricanes for development into a natural fuel photo series.

2. Determine what variables were to be measured, how best to inventory those variables, and what variable to use to arrange photo series sites.

3. Locate, photograph and inventory a minimum of 12 sites within the southern pine and hardwood fuelbed types that were impacted by the hurricanes.

4. Reduce and compile the inventory data into a print-ready manuscript, and to print and distribute the photo series volume through the Pacific Northwest Research Station.

The major deliverable of this project is completed and is the published Post-Hurricane Natural Fuels Photos Series, Volume XII. This photo series is available upon request free of charge from the Pacific Northwest Research Station Fire and Environmental Research Applications team (http://www.fs.fed.us/pnw/fera/) and the Pacific Northwest Research Station (http://www.fs.fed.us/pnw/). The sites within this photo series will be added to the Digital Photo Series, a Joint Fire Science Project (JFSP- 04-4-1-02) in January, 2010, for easy access through the web (http://depts.washington.edu/nwfire/dps/).

III. STUDY DESCRIPTION AND LOCATION

The principal and co-principal investigators and local fire and fuel authorities (Caroline Noble (National Park Service); Dave Brownlie (US Fish and Wildlife Service); Bruce Davenport (U.S. Forest Service), and Kevin Heirs (Joseph Jones Ecological Research Center and Department of Defense Air Force) participated in two planning meetings and reconnaissance trips in 2006 and 2008 prior to selection of the photo series sites. This informal needs assessment resulted in selection of two post-hurricane series for this JFSP-sponsored Natural Fuels Photo Series development project (table 1, figure 1). The two series included: (1) Gulf Coast dominated by mixed shortleaf pine—loblolly pine with hardwood understory forest species with damage following hurricane Ike (2008) and (2) Atlantic Coast dominated by longleaf pine/saw palmetto flatwoods with a heavy shrub understory with damage following hurricanes Francis (2004), Jeanne (2004), and Katrina (2005). In addition, input at these meetings provided a list of fuel characteristics to be measured and a description of the variable that would be used to arrange the sites in each series.

Table 1. Fuelbed types, location, number of sites, photo series site name, and photo series published for this project.

Fuelbed Type	Location	Sites	Name	Photo Series Title
Gulf Coast	Texas	13	GC 1-13	Stereo Photo Series for Quantifying Natural Fuels Volume XII: Post-Hurricane fuels in the Forests of the Southeast United States (please see attachment).
Atlantic Coast	Florida	7	AC 1-7	

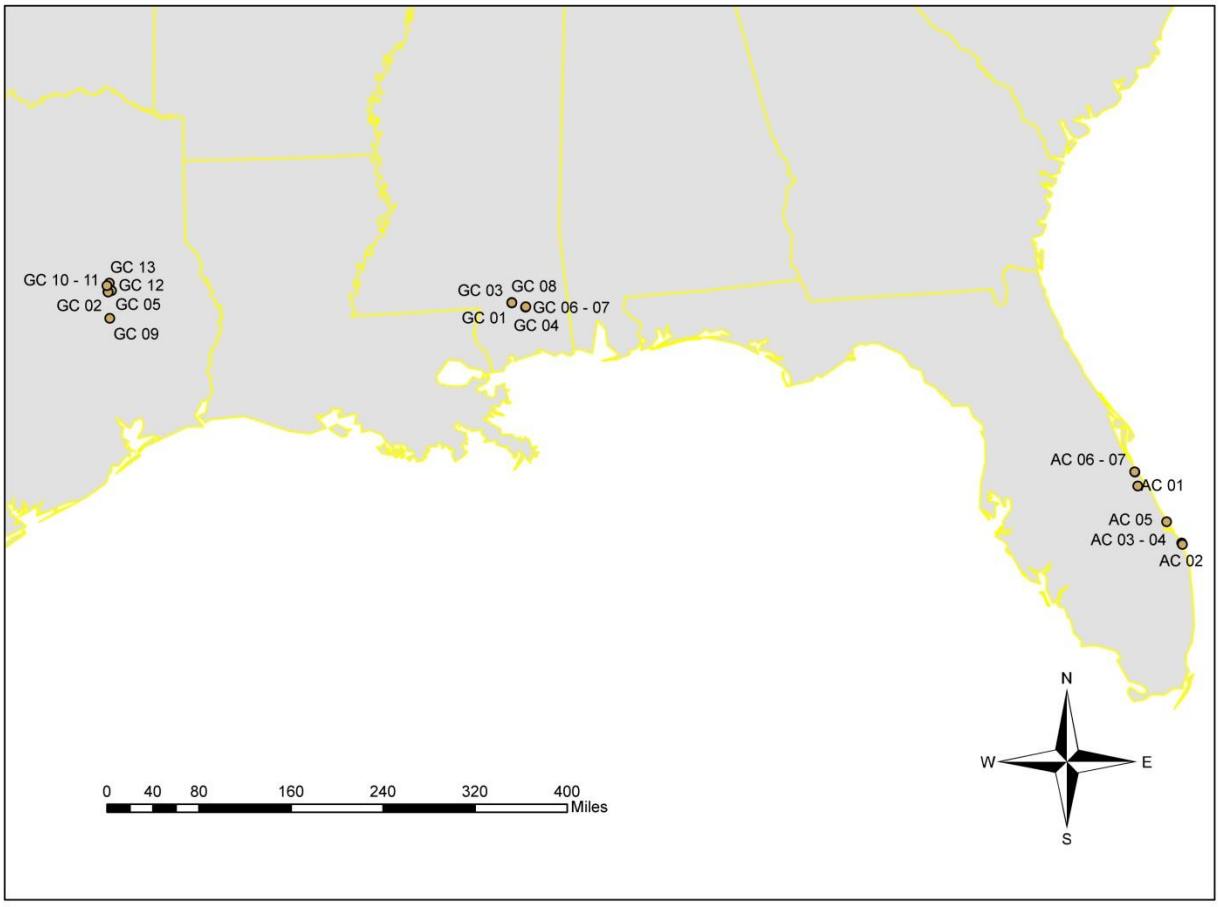

Figure 1. Location of Gulf Coast (GC 1-13) and Atlantic Coast (AC 1-7) photo series sites.

SITE INFORMATION

Single and stereo photographs were taken and fuel loading, stand structure, and composition data were collected by using the procedures of Maxwell and Ward (1980) as a guide (figure 2). The three-dimensional image obtained by viewing the photographs with a stereoscope improves the ability of the land manager to appraise natural fuel, vegetation, and stand structure conditions. A larger, wide-angle photograph was included for additional comparisons. Summary data for each site relate to the field of view of the stereo-pair photographs.

The camera point of each site was located with a global positioning system (GPS) receiver using the WGS-84 datum. Aspect and slope were measured with a compass and clinometer, respectively. Ecological community classification (to the association level; NatureServe 2009), an indicator of current vegetation composition, was assigned for all sites. In addition, Society of American Foresters (SAF) cover type (Eyre 1980) was assigned to describe forest structure for each site. Sites impacted by hurricanes Francis (2004), Jeanne (2004), Katrina (2005), and Ike (2008) were sampled 1 month to 2.5 years post-hurricane.

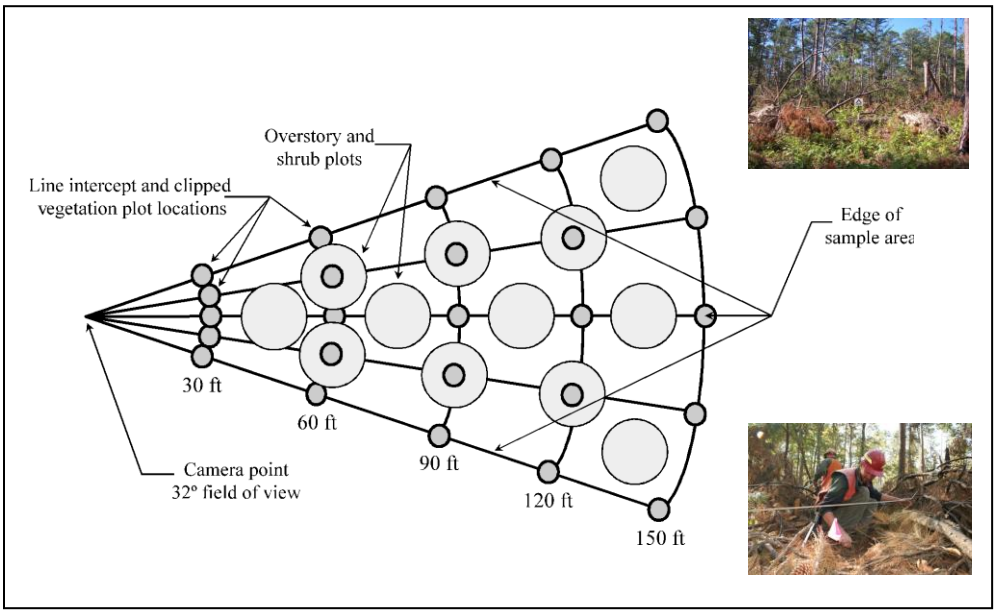

Figure 2. Photo series sampling layout. Forty random azimuth line transects (one at each point on the 30- and 150-foot arcs, and two at each point on the 60-, 90-, and 120-foot arcs) and 12 clipped vegetation plots (two to three per arc) were located within the sample area. Trees, shrubs, and seedlings were inventoried on 12 systematically located sample plots.

PHOTOGRAPH AND INFORMATION ARRANGEMENT

The photographs and accompanying data summaries were presented as single sites organized into two series. Each site was arranged to occupy two facing pages. The upper page contains the wide-angle (50mm) photograph and general site, stand, and forest floor information. The lower page includes the stereo-pair photographs and summaries of overstory structure and composition, understory vegetation structure and composition, and downed woody material loading and density by size class.

STAND INFORMATION

Shrub, forb, and graminoid species coverage was estimated by using line intercept transects (Canfield 1941). Tree and understory species (shrub, forb, and graminoid species) present at a site are listed in order of abundance.[1] The listing of understory species was not meant to be a complete vegetation inventory and may represent only a portion of the actual species richness of the sampled areas. The percentage of standing dead trees and trees with snapped off boles was determined by sampling within the site (fig. 1). Crown closure was measured with a forest densitometer (84 systematically located points). Seedling composition and density were determined either by using twelve 0.002-acre circular plots or six 43.06-square-foot square plots; all trees less than 4.5 feet tall were considered seedlings. *Quercus* species with a shrub-like growth habit were not counted as seedlings.[2]

FOREST FLOOR INFORMATION

Litter and duff were collected in three to six 5.38-square-foot plots, ovendried, and weighed to compute loading on an area basis. Forest floor material is classified following the scheme outlined in Pritchett (1979), where the litter, or L-layer, is comprised of dead, undecomposed vegetation (including dead grass material that was detached from the plant base), and the duff, a combination of the F- and H-layers, consisting of dead vegetation in various stages of decay. Additionally, in sites with recent hurricane damage, conifer needles still attached to broken-off crowns lying within a projected columnar space above the 5.38-square-foot plots were collected, processed, and reported as "crown litter."

SAPLINGS AND TREES

All overstory trees and saplings (i.e., trees ≥4.5 feet tall) within the sample area were counted and measured (fig. 1). Tree measurement data were summarized by diameter at breast height (d.b.h.),[3] size class, and by tree status (all, live, or dead). Trees that were snapped off during the hurricane were also noted. Height to crown base (reported as ladder fuel height in previous photo series volumes) was defined as the height of the lowest, continuous live or dead branch material of the tree canopy, and height to live crown was defined as the height of the lowest continuous live branches of the tree canopy. Live crown mass (branchwood and foliage) was calculated from species- and size-specific allometric equations (Baldwin 1989, Clark and Schroeder 1985, Clark et al. 1986, Ker 1980, Loomis and Blank 1981, Loomis et al. 1966, Martin et al. 1998, Perala 1993, Taras 1980, Taras and Phillips 1978, Ter-Mikaelian and Korzukhin 1997). Generalized composite equations were used when species-specific equations were not available in the literature. A size-specific composite "soft hardwoods" equation was substituted for *Ilex* spp., *Ilex vomitoria*, and *Morrella cerifera* (Clark and Schroeder 1985). A size-specific composite "hard

[1] A list of scientific and common species names used in this volume is included for each series.
[2] *Quercus* species with a shrub-like growth form are listed in the "Notes to Users" section before each series.
[3] D.b.h. is measured 4.5 feet above the ground.

hardwoods" equation was substituted for *Magnolia spp., Osmanthus americanus, Quercus laevis, Quercus laurifolia,* and *Quercus myrtiefolia* (Clark and Schroeder 1985).

UNDERSTORY VEGETATION

Understory species coverage was estimated by using line intercept transects (Canfield 1941). Where species-specific coverage is not reported, understory vegetation coverage was estimated by lifeform category (shrub, forb, or graminoid) by using the line intercept transects. Understory vegetation heights were measured at 39 points located systematically throughout the sample area. Understory vegetation biomass was determined by sampling three to six square, clipped vegetation plots also located systematically throughout the sample area (fig. 1). Shrubs were collected in 43.06-square-foot plots; graminoids and forbs were collected in 10.76-square-foot plots. All live and dead understory vegetation (regardless of size) rooted in each plot was clipped at ground level, separated, and returned to the laboratory for oven drying. Understory vegetation and other collected material were ovendried at a minimum of 158° F for at least 48 hours before weighing and determination of area loading.

WOODY MATERIAL

Measurement techniques used for inventorying dead and down woody material were patterned after the planar intersect method outlined by Brown (1974) and described by Maxwell and Ward (1980). Twenty-one transects of random azimuth starting at 15 systematically located points within the sample area were used to determine woody material loading and density (fig. 1). Woody material data are reported by size classes that correspond to timelag fuel classes used in fire behavior modeling (Burgan and Rothermel 1984).[4] Woody material in 1-hour, 10-hour, and 100-hour size classes was tallied on transects that were 3 feet, 10 feet, and 60 feet long, respectively. The decay class and the actual diameter at the point of intersection were measured for all pieces >3 inches in diameter. All woody material <3 inches in diameter was considered sound. Woody material loading and woody material density were calculated from relationships that use number of pieces intersected and transect length (and wood specific gravity for loading) developed by Brown (1974) and Safranyik and Linton (1987), respectively.

IV. KEY RESULTS

The sites in this photo series are ordered by increasing total downed woody material loading. The loadings ranged from 7.8-88.2 tons per acre for the Gulf Coast sites and 8.9-46.4 tons per acre for the Atlantic coast sites (figure 3). The ranges of loadings in fuelbed categories of trees, shrubs, litter and duff are presented in table 2. We believe the variability found in hurricane damaged sites of the southeastern United States is accounted for in this photo series and will be a valuable addition to the tools available for assessing fuel loads and other fuel characteristics following wind damage. This volume presents a more extensive survey of hurricane-generated fuels than the earlier work published by Wade et al. (1993).

[4] 1-, 10-, 100- and 1000-hour timelag fuels are defined as woody material ≤0.25 inch, 0.26-1.0 inch, 1.1-3.0 inches, and >3.0 inches in diameter, respectively.

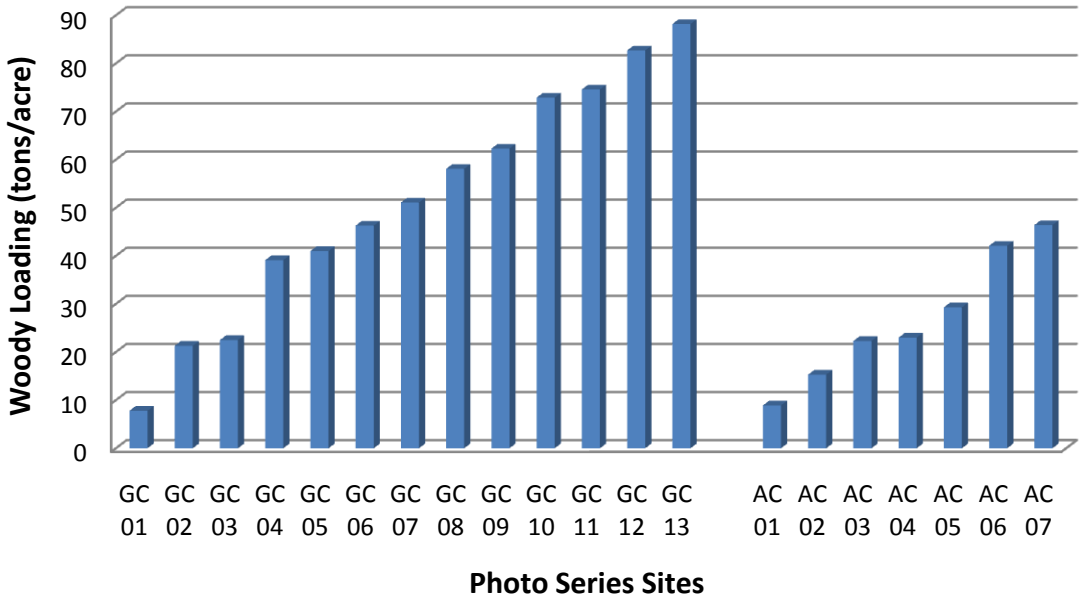

Figure 3. Post-hurricane photo sites order by downed woody fuel loading (tons/acre) for the Gulf Coast (GC) and Atlantic Coast (AC) series.

Table 2. Data ranges for various fuelbed categories collected.

Fuelbed Categories	**Gulf Coast**	**Atlantic Coast**
Trees >4" (stems/acre)	29-224	33-253
Shrubs (lbs/acre)	382-1,756	3,694-9,472
Grasses (lbs/acre)	0.0-374	0.0-724
Downed woody (tons/acre)	7.8-88.2	8.9-46.4
Litter depth (inches)	0.5-2.8	0.0-3.5
Duff depth (inches)	0.0-4.6	0.1-3.9

V. MANAGEMENT IMPLICATIONS

This photo series will provide a quick and easy means for quantifying and describing existing fuel properties often reducing the field time over other inventory methods. Federal, state, and private fuel and fire managers and Incident Management teams will use this photo series to assist in assessing fire severity, fuel treatment effectiveness, carbon stores, air pollutant emissions, and other effects of fire. During the month of December, 2009 over 400 copies of the photo series were distributed attests to the desire for this tool.

The fuelbed data base developed from the project is unique and will provide the opportunity for

managers to build more robust fuelbeds in the Fuel Characteristic Classification System. This will provide (1) the ability to evaluate fire potentials and surface fire behavior; (2) inputs for Consume and the First Order Fire Effects models to evaluate fuel consumption, fire effects, and smoke production; and (3) fuelbeds for assessing wildlife habitat.

VI. RELATIONSHIP WITH RECENT FINDINGS AND ONGOING WORK

The project provides a valuable tool for field assessing fuelbed characteristics in forests damaged by hurricanes in the southeastern United States. It also provides the only data set covering the wide range of fuel loading variability seen in wind damaged forests of the Souhtheast. As shown in figure 3, loadings ranged from 7.8-88.2 tons per acre for the Gulf Coast sites and 8.9-46.4 tons per acre for the Atlantic coast sites. This is a much broader range than the 12-36 tons/acre loading presented by Wade et al. (1993).

This data can be used to build fuelbeds in the Fuel Characteristics Classification System (JFSP - 98-1-1-06) to represent hurricane damaged forested fuelbeds in the southeastern United States. The fuelbeds have been processed through the FCCS in a testing environment and assessed for surface fire behavior and crown fire potential as well as reaction intensity, rate of spread and flamelength under various slope, wind, and moisture conditions. These fuelbed characteristics and fire behavior outputs will be a valuable asset for fire and fuel managers and Incident Management Teams in assessing fire potential immediately following hurricane damage in forests and the effectiveness of follow-up fuel treatment options. These fuelbeds could also provide improved assessed of carbon accounts represented by these damaged forests.

VII. FUTURE WORK NEEDED

We feel this new photo series captures the variability in fuelbed characteristics found in the majority of wind damaged forests of the southeastern United States. Although the tool can be extrapolated to include ice damaged forests in the same region, there are critical differences between wind damaged and ice damaged fuelbeds. A photo series that specifically targets ice damaged forests may be needed. For example, ice damaged forests are often concentrated in hardwood stands and include a greater concentration of small branches and limbs. This photo series concentrated on pine forest and the fuelbeds were generally composed of entire trees.

VIII. DELIVERABLES AND CROSS-WALK

The primary deliverable product for the project was one printed volume of the Post-Hurricane Natural Fuels Photo Series in Forests of the Southeast United States, three progress reports, and a website (table 3). One thousand copies of the volume were printed by Monarch Printing and are being distributed free of charge from the Fire Environmental Research Applications Team at the Pacific Wildland Fire Science Laboratory, Seattle, WA and the Pacific Northwest Research Station headquarters in Portland, OR . Two printed copies (more if requested) and an electronic PDF file have been provided to the JFSP. The photo series tutorial (JFSP 04-4-1-19) will be updated in January 2010 to account for this new photo series. This series has been shown and demonstrated at many training sessions and conferences. Both efforts were beyond the scope of the project (table 4). In addition, data collected for this photo series effort allowed the Fuel

Characteristic Classification System (JFSP 98-1-1-06; Ottmar et al. 2007) to be more robust and include fuelbeds that represent hurricane damage as a change agent that were historically data-poor.

Table 3. Comparison of proposed and actual deliverables.

Proposed	**Delivered**	**Status**
Final	Final Report	Completed
One photo series volume	**Vihnanek, Robert E.; Balog, Cameron S.; Wright, Clinton S.; Ottmar, Roger D.; Kelly, Jeffrey W. 2009.** Stereo photo series for quantifying natural fuels. Volume XII: Post-hurricane fuels in forests of the southeast United States. Gen. Tech. Rep. PNW-GTR-803 Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 53 p. One thousand copies of this Volume have been printed by Monarch Printing and are available free of charge from the Pacific Norwest Research Station's Publication Information System. We have also purchased 700 copies of over prints for a total of 1,700 copies for distribution.	Completed
Implementation into Digital Photo series project (JFSP- 04-4-1-02)	Digital photographs and data provided for implementation into Digital Photo series project (JFSP- 04-4-1-02). http://depts.washington.edu/nwfire/dps/	Will be completed in January, 2010
Web Page	http://www.fs.fed.us/pnw/fera/photoseries.html	Done
Training	Thirty-five photo series presentation and exercises at RX 410 (Smoke management), RX 300, (Burn Boss), RX 310 (Fire Effects) national and regional training sessions, two presentations at Technical Fire Management, and five 4-hour and 3-day workshops at the Fire Congress Conferences in San Diego, CA in 2008 and the 4th Fire Congress in Savannah, Georgia in 2009.	Done

Table 4. Additional deliverables completed that were not included in the original proposal.

Additional Deliverables Completed But Not Originally Proposed
One poster presentations and published abstract, Fourth Fire Congress Conference, Savannah, Georgia, 2009
150 photo post-hurricane photos series were distributed at the Savannah Conference, 2009.
The photo series tutorial (JFSP 04-4-1-19) will be updated in January 2010 to reflect the hurricane photo series.
Implemented into Rx 410, Rx 310, Rx 300, Technical Fire Management, and University of Idaho 401 series lesson plans.

WEB PAGE

A web page including project progress, citation, and ordering information was established at www.fs.fed.us/pnw/fera/photoseries.html.

POSTERS, ABSTRACTS, AND PRESENTATIONS

Jon E. Dvorak, Cameron S. Balog, Robert E. Vihnanek, and Roger D. Ottmar. Stereo photo series for quantifying natural fuels: Post-hurricane fuels in forests of the southeast United States. Poster presentation, 4th International Fire and Ecology Management Conference, Savannah, GA, November 30-December 4, 2009

PUBLICATION

Vihnanek, Robert E.; Balog, Cameron S.; Wright, Clinton S.; Ottmar, Roger D.; Kelly, Jeffrey W. 2009. Stereo photo series for quantifying natural fuels. Volume XII: Post-hurricane fuels in forests of the Southeast United States. Gen. Tech. Rep. PNW-GTR-803. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 53 p.

Abstract: Two series of single and stereo photographs display a range of natural conditions and fuel loadings in post hurricane forests in the southeastern United States. Each group of photos includes inventory information summarizing vegetation composition, structure and loading, woody material loading and density by size class, forest floor loading, and various site characteristics. The natural fuels photo series is designed to help land managers appraise fuel and vegetation conditions in natural settings.

Keywords: Woody material, biomass, fuel loading, natural fuels, hurricane, wind damage, blowdown, sand hill, sand pine scrub, longleaf pine, *Pinus palistris*, loblolly pine, *Pinus taeda*, sand pine, *Pine clausa*, shortleaf pine, *Pinus echinata*, slash pine, *Pinus elliotti*

DIGITAL PHOTO SERIES IMPLEMENTATION

The Post-Hurricane Fuels in Forests of the Southeast United States photo series will be implemented into the Digital Photo Series (JFSP- 04-4-1-02) in January 2010 and will be available for viewing at http://depts.washington.edu/nwfire/dps/.

Post-Hurricane Photo Series Demonstrations

- Technical Fire Management, Bothell, WA, 2009
- Rx410, Albuquerque, Redmond, Missoula, Boise, Denver, Tallahassee, 2008 and 2009,2007, 2008, 2009; Rx410 Grand Rapids, MN 2009
- Joseph Jones Ecological Research Center regional Fuels Workshop, Ichauway, GA, 2008 and 2009
- DOD—Fort Gordon Regional Fuels Workshop, Fort Gordon, GA 2008
- US Forest Service Region 6 3-day regional fuels workshop, Redmond, OR 2009
- San Diego Fire Congress workshop, San Diego, CA, 2008
- Savannah Fire Congress Conference, Savannah, GA, 2009
- Smoke Modeling workshop, Kinston, NC, 2009

CONSULTATIONS

Over the past year, the principle investigator consulted with many land managers, regulators, and scientists with regard to the post-hurricane photo series use and future development. These included fuel and fire managers of the USDI Fish and Wildlife Service and National Park Service, US Forest Service, Department of Defense, Army and Air Force, and the Division of Forestry in the States of Georgia, Florida, Alabama, North Carolina, and South Carolina.

TUTORIAL

A web-based self-taught tutorial along with an instructor's guide and student workbook for the photo series was developed (JFSP 04-4-1-19) and will be updated to include the Post-Hurricane Fuels Photo Series in Forests of the Southeast United States in January 2010. The photo series tutorial can be accessed through a web-browser or down-loaded directly from http://www.fs.fed.us/pnw/fera/products/tutorials/.

LESSON PLANS AND TRAINING

The Post Hurricane Photo series has been implemented into the "how to use the photo series" lesson plan that was developed and implemented into the RX- 410 Smoke management, RX 310, Fire Effects, and RX 300 Prescribed Fire Burn Boss, lessons. Finally, the Post-Hurricane photo series has been added to the University of Idaho's 401 fuels management series and into the Technical Fire Management fuels module.

TRAINING

The principal Investigator taught how to use the photo series approximately 35 times at both National and regional training sessions. In addition, photo series training was given to a group of Mexican fire management professionals at the Forestry Center in Cuidad Guzman, Mexico from February 21-March 2, 2005.

IX. LITERATURE CITED

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