Flood Impact Assessment of Hurricane Katrina In Orleans Parish

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In the fall of 2005, Hurricane Katrina, a category 5 hurricane with winds up to 175 mph, made landfall on Louisiana, among other states, resulting in extensive flooding. The city of New Orleans experienced a particularly large amount of flooding which caused huge amounts of displaced persons and property damages.

Our project will examine the flood damages done to the city by calculating the area of the flooding. By finding the extent of the flooding in the city, we are able to persons displaced and housing units damaged. We will use remotely sensed data to classify the extent what flooding did occur on land within the city. We will perform land classification for slightly before the storm to immediately after to calculate exactly where and how much land became flooded.

We have limited the area of which we will examine to the Orleans Parish. The Orleans Parish, similar to a county, encompasses multiple cities as well as the entire city of New Orleans. The parish sits on the southern end of Louisiana, with the Gulf of Mexico at its south and east borders. The northern border of the parish is on Lake Pontchartrain. A neighboring parish encompasses some highly developed lands expanding from the city of New Orleans, but is not included in our analysis since Orleans Parish encompasses the majority of the population of the metropolitan area and the official extent of the city.

The area contains large extents of wetlands as well as uplands that have been developed for urban, residential, and some agricultural use. Due to the extremely low elevation (below sea level near the northern border of the parish), the land is extremely vulnerable to flooding. Though the land inclines to a few meters above sea level near the river, much of the land on which developed urban and residential areas lie is below sea level. Remotely sensed images are highly useful in calculating flood extent through the analysis of multiple spectral

numbers an area produces. Also, census data, including population and housing density maps will be utilized in order to analyze the estimated flooding effects.

To reach our objective, we will use remotely sensed imagery to create land classification of the extensive area for before and after the storm. We will perform supervised classifications on 30 meter resolution Landsat 5 images, using bands 1-4 and band 7 which will give us visible light, near infrared and mid infrared to use in creating classifications. Using satellite imagery with infrared bands will aid in producing accurate classifications of land type. After classification we will conduct change detection and analyze which urban areas changed to flooded in the post-storm thematic classification. We will then use the amount of flooded urban area accompanied by census information to make final conclusions on damages done to Orleans Parish. An accuracy assessment will be performed using National Agriculture Imagery Program images.

Materials and Tools

August 26, 2005 30m, Land Sat 5 imagery of Orleans County, using bands 1,2,3,4, and 7, from Earth Explorer
September 7, 2005 30m, Land Sat 5 imagery of Orleans County, using bands 1,2,3,4, and 7, from Earth Explorer
2005 2m, NAIP mosaic of ortho imagery from USDA, from Data Gateway
Orleans County border shape, file, from Census Tiger
Census data of Orleans County, from US Census

ERDAS
Masking Tool
Supervised Classification Tool
Change Detection Tool
Accuracy Assessment Tool

ARC10
Combining Bands Tool
Mask Extraction Tool
Raster-Vector Conversion Tool

Procedures

Acquiring data

1. Obtain base maps for pre and post Katrina through Earth Explorer
2. Do preliminary analysis on photos to ensure that they are useable, by using the image preview
3. Obtain reference data from Data Gateway
4. Obtain shape file of Orleans County's border from Census Tiger
5. Obtain census data of economics, population, and land area from census.gov

Using data

1. Using ArcMap10, stack bands, 1,2,3,4, and 7
   Toolbox->Data Management Tools->Raster->Raster Processing->Composite Bands
2. With bands stacked together, use Orleans County border shape file to extract necessary sections of base maps
   Toolbox->Spatial Analysis Tools->Extraction->Extract by Mask
   Input Raster: Pre-Katrina Base Map + Post-Katrina Base Map
   Input Mask: Orleans County Border Shape File
3. Bring extracted base maps into ERDAS
4. Begin supervised classification
   Pre-Katrina base map
   -Create a new AOI layer
   -Created classes for flooded, urban, vegetation, water, and wetlands
   -Take samples for each of the classes in signature editor
   -Only take one pixel sample for flooded class
   -Merge multiple samples of the same classes together
   -Run maximum likelihood classification with sample pixels
   Post-Katrina base map
   -Create a new AOI layer
   -Created classes for flooded, urban, vegetation, water, and wetlands
   -Take samples for each of the classes in signature editor
   -Merge multiple samples of the same classes together
   -Run maximum likelihood classification with sample pixels
5. Amend errors from ERDAS classification *(ERDAS classified in a square as opposed to an irregular shape)*
   -Convert Orleans County Border Shape File into a raster in Arcmap10
   Toolbox->Conversion Tools-> To Raster->Polygon to Raster
   Input: Orleans County Border Shape File
   -Bring pseudo-shape file into ERDAS
   -Extract classified Pre and Post maps
   -Subset and Chip->Mask

Input 1: Classified map
Input 2: Raster-shape file

6. Accuracy assessment
   Pre-Katrina Classified Map
   -Extract classified map to fit NAIP data
   -Subset and Chip->Mast
   Input 1: Classified Pre-Katina Map
   Input 2: NAIP Orleans reference data.
   -Create 150 random points with at least 20 points in each class
   -Match randomly generated points up with NAIP data
   -Produce Report including error matrix, accuracy totals, and kappa statistics
   Post-Katrina Classified Map
   -Unable to attain reference data for the exact post-classification date
7. Run Thematic Change Detection
   -Run Matrix Union In ERDAS
   Input 1: Pre-Katrina Classified Map
   Input 2: Post-Katrina Classified Map
   -Analyze output
8. Analyze Census data
   -Compare population densities and area of flooded land using Excel

Results

We assessed To-From land change and total area in land change in square miles. Urban area decreased from an original 88 sq. miles by 51 sq. miles. There were a total of 45 sq. miles of the Flooded class type and an increase of 6 sq. miles of the Water class. Unexpectedly, the Wetlands class area decreased by 23 sq. miles. We attribute this to the increase of vegetation by 23 sq. miles. We believe the lower DN values of the presumably flooded Wetlands areas were indicative to the training area Vegetation DN values. So, our assessment found that urban area decreased by 51 sq. miles, 33 sq. miles being a change of Urban to Flooded and the rest attributed to expanse and local change of water and wetlands.

Given the loss of 51 sq. miles of urban area due to flooding and the average population density of the total land area we estimate roughly 134,585 persons displaced. Focusing on urban area density, we estimate 281,332 persons were displaced due to flooding. Land area

would be more conservative, urban more liberal, in respect to densities. Calculating property damages by land area, we estimate 16,697 units damaged; calculating by urban, we estimate 34,916 units damaged. These numbers can be further analyzed to evaluate population and migration trends as well as monetary costs attributed to houses damaged.

Quantitative results of the change detection for further evaluation can be found in Appendix II.

Discussion

Though the general process of collecting data, performing classifications, and evaluating change detection is very straightforward, we encountered many technical problems. Most problems were due to our unfamiliarity with the software and how to apply somewhat varied data and processes to our previous basic trials and experiences. There were also inconsistencies and inaccuracies that must occur in any extensive project involving remotely sensed data.

We decided on using Landsat 5 imagery because of it provided all the visible and infrared bands we needed to classify land cover and due to its easy availability. Luckily, we found images with appropriate pre and post storm dates. They also required no preprocessing, including any atmospheric or cloud correction and no rectification. The availability of Landsat images really eased the process of finding data and beginning further work on the project.

Problems started to arise once we needed to define our area of examination from the Landsat imagery. After consideration of our experience with other GISs and advice from the TA, we chose to extract using ArcMap. We ran into a few problems here finding the extraction method that would work with the file formats we had and then creating a final extracted file type that worked back in ERDAS. Trying a few different extraction methods and typing ".img"

into the output file was crucial in creating useable EM data that defined the correct area of interest, Orleans Parish.

A problem that showed up long after it occurred was an inconsistency in Orleans County shapefile data that led to inability to compare classifications for change detection. Willy and I used data from two different sources and overlooked their boundary differences. Due to the inconsistencies between Orleans Parish shapefiles, it was necessary for the post-storm extraction from Landsat imagery and supervised classification to be performed again, otherwise the pre and post-storm classification images would cover different extents and make change detection impossible. Having the necessity to basically re-do the technical steps of the project allowed for opportunity to hone skills and check for possible mistakes the first time around. It seems that even if you have no crucial need to re-do your work to continue the project, it may be helpful to follow the steps again for clarification and perfection of the work.

We wanted to obtain "To-From" information on land cover classes, so we had to perform classifications on both pre and post storm imagery. By performing two separate classifications we faced increased inaccuracy and a few technical problems. In defining training areas, creating a Wetlands class proved to be difficult due to the range of spectral variance. In each of our classifications the results were not able to define wetlands very accurately and attributed many pixels in both water and vegetation areas. This inconsistency was emphasized in comparing the two for change detection. Looking back, we would have liked to create a "Non-Flooded" class including anything besides urban or water to avoid slight radiometric discrepancies. There were also clear inaccuracies in where the Flooded area class showed up, including many Flooded pixels in the ocean and in wetlands.

Since the post-storm classification used five classes including Flooded area, the pre-storm classification required an additional class. We created a null class which included one extremely small training area that would not amount to any significant classification.

Our assessment of flood impacts to New Orleans faces uncertainty and limitations. Due to the short time frame, our assessment only included Orleans parish and no neighboring parishes that also hold significant amounts of urban areas that experienced flooding. By evaluating the western and southwestern lying parishes an assessment of the entire metropolitan area could be produced.

Accuracy assessment was limited to 20 points per class for the pre-storm classification. Also, no accuracy assessment was performed on the post-storm classification due to inability to find reference data for the exact date. FEMA provides general flood range maps but we chose not to use them since our classification left many pixels as Vegetation or Urban within the extent that of flooding but were not necessarily flooded.

Landsat data is sufficient in creating a general idea of where flooding occurred; however, hyperspectral data would provide additional radiometric information that could aid in distinguishing between land types more clearly. Our training areas produced large amounts of classifications confused between vegetation, wetland, water, and flooded area which could be more accurately defined. Again, expanding the area of analysis to neighboring counties would provide a more thorough representation of the metropolitan areas' flood extent.

Our estimations of persons displaced due to the expanse and flooded area and loss of urban area are rough. Inconsistencies between our calculated densities and given census densities of housing units could be cause for inaccuracy as well as our dependence on a county

wide population density and not a urban-specific population density. Also, there was continual change in flooding to the New Orleans area due to additional post-storm rain and drainage of flooded land. Our results only apply to September 7th, so future work could examine multiple dates after the storm.

Further analysis of our persons displaced results and housing units damaged could be done to evaluate migrating population effects and property and insurance damage costs. This report supplies

References

Census Tiger/Linefiles; census.gov/geo/www/tiger

Data Gateway; datagateway.nrcs.usda.gov

Earth Explorer; earthexplorer.usgs.gov

NASA Hurricane Season 2005: Katrina;

nasa.gov/vision/earth/lookingatearth/h2005_katrina.html

United States Census; census.gov

Apendix I- CLASSIFICATION ACCURACY ASSESSMENT REPORT

ERROR MATRIX

	Reference Data			
Classified Data	Background	Class 1	Class 2	Class 3
Background	38	4	4	2
Class 1	0	10	11	2
Class 2	0	0	20	0
Class 3	0	2	3	11
Class 4	0	0	0	0
Class 5	0	0	0	0
Column Total	38	16	38	15

	Reference Data	
Classified Data	Class 4	Class 5
Background	1	5
Class 1	0	2
Class 2	0	0
Class 3	0	8
Class 4	0	0
Class 5	0	27
Column Total	1	42

----- End of Error Matrix ----

ACCURACY TOTALS

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Class 0	38	54	38	---	---
Class 1	16	25	10	62.50%	40.00%
Class 2	38	20	20	52.63%	100.00%
Class 3	15	24	11	73.33%	45.83%
Class 4	1	0	0	---	---
Class 5	42	27	27	64.29%	100.00%
Totals	150	150	106		

Overall Classification Accuracy = 70.67%

----- End of Accuracy Totals ---

KAPPA (K^) STATISTICS

Overall Kappa Statistics = 0.6291

Conditional Kappa for each Category.

Class Name	Kappa
Class 0	0.6032
Class 1	0.3284
Class 2	1.0000
Class 3	0.3981
Class 4	0.0000
Class 5	1.0000

----- End of Kappa Statistics -----

Appendix II- Change Detection Tabulation and Quantitative Analysis

Change Detection:

Before	After	Pixel Values	Values/-(Total-Unclass)	Area(sqmile)
Unclassified	Unclassified	1143734	Null	Null
Urban	Urban	95184	0.094384937	33.05454883
Urban	Vegetation	38448	0.038125232	13.35183742
Urban	Wetlands	16831	0.016689705	5.844901573
Urban	Flooded	96441	0.095631385	33.49106723
Urban	Water	9148	0.009071203	3.17682607
Vegetation	Urban	625	0.000619753	0.217043758
Vegetation	Vegetation	31987	0.031718471	11.10812588
Vegetation	Wetlands	2546	0.002524627	0.884149451
Vegetation	Flooded	3225	0.003197926	1.119945789
Vegetation	Water	50	4.95803E-05	0.017363501
Wetlands	Urban	11581	0.011483778	4.02173401
Wetlands	Vegetation	35363	0.03506613	12.28050944
Wetlands	Wetlands	142446	0.141250176	49.46722414
Wetlands	Flooded	17277	0.017131961	5.999783999
Wetlands	Water	31820	0.031552873	11.05013178
Flooded	Urban	0	0	0
Flooded	Vegetation	0	0	0
Flooded	Wetlands	0	0	0
Flooded	Flooded	0	0	0
Flooded	Water	0	0	0
Water	Urban	35	3.47062E-05	0.01215445
Water	Vegetation	455	0.00045118	0.158007855
Water	Wetlands	9526	0.00944603	3.308094135
Water	Flooded	12733	0.012626107	4.421789064
Water	Water	452745	0.448944238	157.2247616
	Total:	2152200	Null	Null
	Minus Unclassified:	1008466	1	350.21

Census Data:

Orleans Parish:	Population	Housing Unitss	Total Area	Water Area	Land Area
	484,674	60,154	350.21	169.66	180.56

Pre-Katrina:

Classes	Pixel Values	Values/(Total-Unclassified)	Area(sqmile)	Land Area (sqmile)
Unclassified	1143734	Null	Null	
Urban	256052	0.253902462	88.91918113	
Vegetation	38433	0.038110358	13.34662837	
Wetlands	238487	0.236484919	82.81938337	185.0851929
Flooded	0	0	0	
Water	475494	0.471502262	165.1248071	
Total:	2152200	Null	Null	
Minus Unclassified:	1008466	1	350.21	

Post-Katrina:

Unclassified	1143734	Null	Null	
Urban	107425	0.106523175	37.30548105	
Vegetation	106253	0.105361014	36.89848059	
Wetlands	171349	0.169910537	59.5043693	133.7083309
Flooded	129676	0.128587379	45.03258609	
Water	493763	0.489617895	171.469083	
Total:	2152200	Null	Null	
Minus Unclassified:	1008466	1	350.21	

Pre-Katrina Density:

Population(P/m):	Total Area	1383.952486
	Land Area	2618.653564
	Urban Area	5450.72496
Housing Units(U/m):		
	Total Area	171.7655121
	Land Area	325.0070903
	Urban Area	676.5019564

Post-Katrina Calculations:

Population Displaced:		
	Land Area	134538.2026
	Urban Area	281332.0833
Housing Units Damage:		
	Land Area	16697.84441
	Urban Area	34916.76909

Population Density	Housing unit Density
2,684.30	1,191.30