Temporal Study of Landscape Change After Hurricane Katrina

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INTRODUCTION

Temporal analysis can be used to show how the world around us is always changing. The changes that occur could be those which are natural and will occur throughout the lifespan of planet Earth. However, change can also be more sudden and have a devastating impact on the landscape. An example of this type of change are natural disasters such as hurricanes and tornadoes. Natural disasters such as these kill people and destroy homes, buildings and surrounding infrastructure.

Understanding how the world looks at different time periods, and the results of how the worlds landscape has changed can tell us a story about its history and also help us predict trends and plan for the future (Yuan, Sawaya, Brian, & Bauer, 2005).

Hypothesis

Remote sensing can be used to study the temporal changes of landscapes after a natural disaster and show trends about how the impacted areas are being rebuilt over time.

Project Objectives

1. Perform spatial analysis from pre and post Hurricane Katrina land classification data that will show areas that were once highly developed in 2005 and were classified differently in 2006.
2. Perform spatial analysis to calculate which areas had the largest amount of shoreline erosion, by comparing areas once classified as shoreline in 2005 that were classified as a water body in 2006.
3. Use analog and digital processing methods to identify patterns on how the redevelopment of Orleans Parish, LA has progressed over time.

BACKGROUND

In August of 2005 Hurricane Katrina went through the states of Louisiana, Mississippi, Alabama and Florida. It reached a category 5 level and became the largest natural disaster in the U.S. Over 1,800 people were killed and many survivors were without homes or shelter. Its destruction cost has been estimated at 81 billion dollars worth of damage (Stoker, Tyler, Turnipseed, Wilson Jr., & Oimoen, 2009).

Among the hardest hit areas from Hurricane Katrina was New Orleans, LA. One of the key factors of why New Orleans incurred such tragic devastation was that the levee system failed, causing major flooding and storm surges to enter the city, of which the majority of the area is below sea level (Stoker, Tyler, Turnipseed, Wilson Jr., & Oimoen, 2009).

Land classification data was obtained by the National Oceanographic and Atmospheric Administration (NOAA) Coastal Services Center (CSC)/Coastal Analysis Program(C-CAP) as TIF files for 2005 and 2006. This classification data is based off of Landsat TM imagery (Land Cover Data for Hurricane Katrina Impacted Areas). Imagery from multiple time periods were also used in this temporal study from the Landsat 7 ETM and Landsat MRLC/MTBS Reflectance sensors.

METHODOLOGY

Pre and post Katrina land classification data was compared for the following categories: Water, Unconsolidated Shore, High and Medium Intensity Developed Land. In addition to performing the comparison with the entire dataset, I created a subset clipped to the extent of Orleans Parish Louisiana. The purpose of this was to study the change at different scales to identify any anomalies.

Using ArcGIS ModelBuilder I was able to develop a model to take the pre and post land use data and extract the different classifications into different raster datasets. Once the different classification datasets were created the data was reclassified from their original values to binary based on if the pixel fell into the land classification categories of interest. Using ArcGIS Spatial Analyst, raster math was performed using the Plus and Times tools. The Plus tool revealed which areas have the same classification value from 2005 and 2006, and what areas have changed to a different land classification. The Times tool was used by multiplying the binary result set with the post Katrina dataset to extract what the new classification values were in 2006.

To identify the hurricane impact and determine the redevelopment progress in the area the Landsat ETM and Landsat MRLC/MTBS Reflectance sensors were used. The study area was limited to Orleans Parish, LA and involved mostly analog (visual) processing to identify patterns of flooding, vegetation degradation and underdeveloped space through a series of images from different time periods. Using the Landsat MRLC/MTBS Reflectance thermal band, I was able to identify highly populated areas based on increased reflectance in the red band, to see the growth trend over time.

RESULTS

Landuse Classification	Location	2005	2006	Change
Water	Hurricane Katrina Impacted Areas	30,519,578	31,187,070	667,492
	Orleans Parish, LA	1,340,084	1,360,861	20,777

Table 1a: Comparison of the total number of pixels with land classifications of "Water" from 2005 to 2006. The increase is an indicator of the amount of flooding that occurred from Hurricane Katrina.

Landuse Classification	Location	2005	2006	Change
Shoreline	Hurricane Katrina Impacted Areas	599,591	570,383	29,208
	Orleans Parish, LA	2,714	2,513	201

Table 1b: Comparison of the total number of pixels with the land classification of "Unconsolidated Shore" from 2005 to 2006. This is an indicator of the amount of beach erosion that occurred from Hurricane Katrina.

Landuse Classification	Location	2005	2006	Change
Developed	Hurricane Katrina Impacted Areas	1,750,618	1,716,317	34,301
	Orleans Parish, LA	154,191	151,437	2,754

Table 1c: Comparison of the total number of pixels with the land classification of "High or Medium Intensity Developed" from 2005 to 2006. The decrease is a possible indicator of the amount of property and infrastructure damage that occurred from Hurricane Katrina.

Top Classification Changes of 2005 Shoreline Areas Hurricane Impacted Areas

Classification Code	Land Classification	%
19	Unconsolidated Shore	88.0
20	Bare Land	1.6
21	Open Water	9.8

Table 2a: Results show that over 10% of the classified unconsolidated shore from 2005, was classified differently after Katrina as either bare land or open water in 2006.

Top Classification Changes of 2005 Shoreline Areas Orleans Parish, LA

Classification Code	Land Classification	%
15	Palustrine Emergent Wetland	3.6
19	Unconsolidated Shore	92.6
20	Bare Land	0.7
21	Open Water	3.1

Table 2b: A smaller study area shows a similar trend where shore is classified as bare land or open water, however there is a high percentage of area that has changed also to Palustrine Emergent Wetland.

Figure 1a: Map of an area outside New Orleans, LA showing high amounts of "Unconsolidated Shore" (Cyan) pre Hurricane Katrina in 2005.

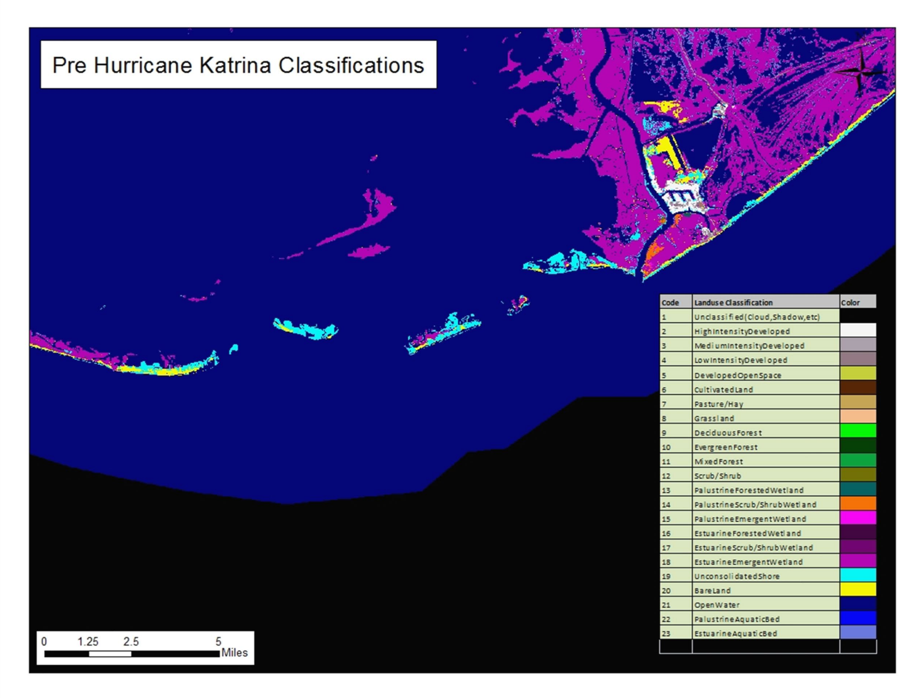
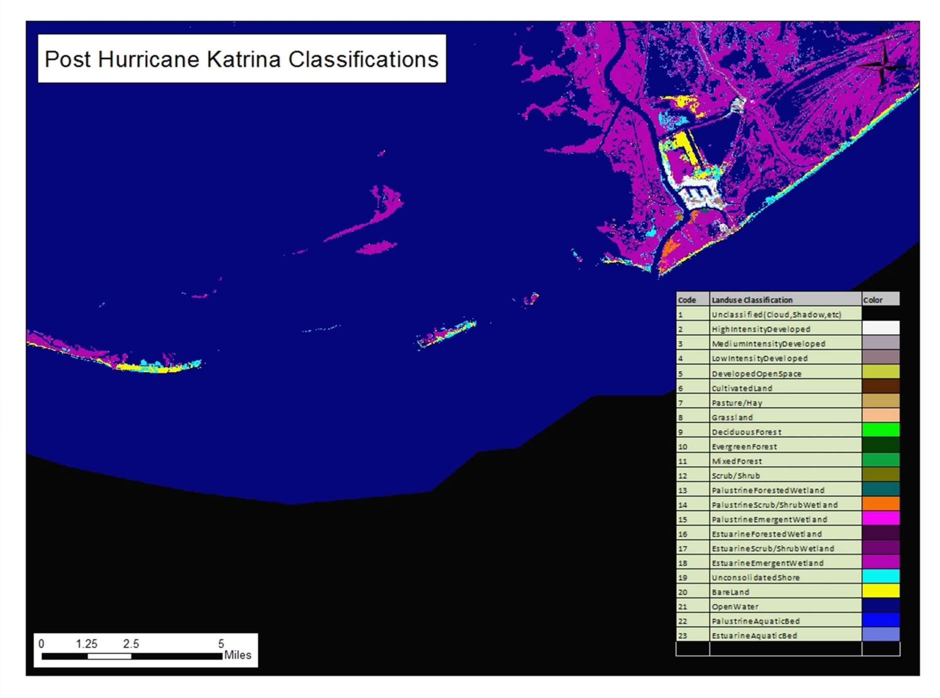


Figure 1b: Same area outside New Orleans, LA showing that much of the "Unconsolidated Shore" from 2005 has been reclassified as "Open Water" (Dark Blue) post Hurricane Katrina in 2006.



MRLC/MTBS Reflectance - Thermal Band - Orleans Parish, LA

Figure 4a: Thermal reflectance pre Hurricane Katrina. The red band represents highly populated areas, one of which is New Orleans. The blue represents mostly water and the green band represents reflectance in areas of open land and vegetation.

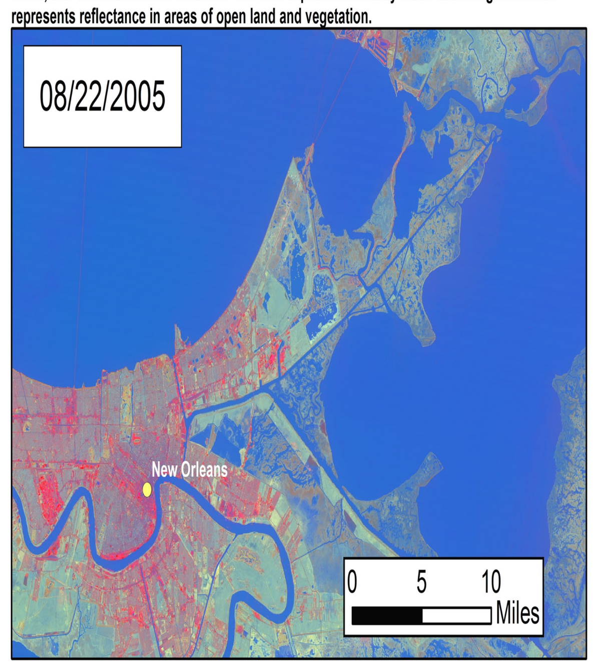


Figure 4b: Thermal reflectance post Hurricane Katrina. Red and green band reflectance is low, while blue band reflectance increases. This highlights which areas have been flooded from the hurricane.

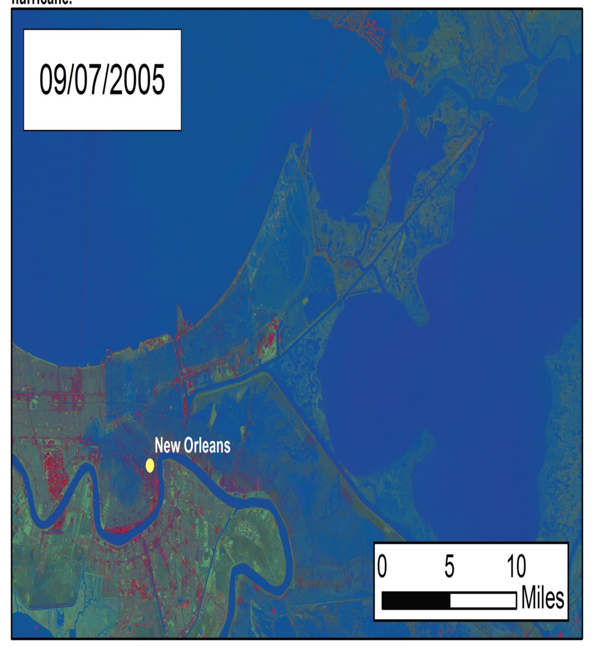


Figure 4c: One year after Hurricane Katrina, the flooding subsides and there is an increased reflectance in the red and green bands indicating that vegetation is starting to grow and land is being redeveloped and urbanized.

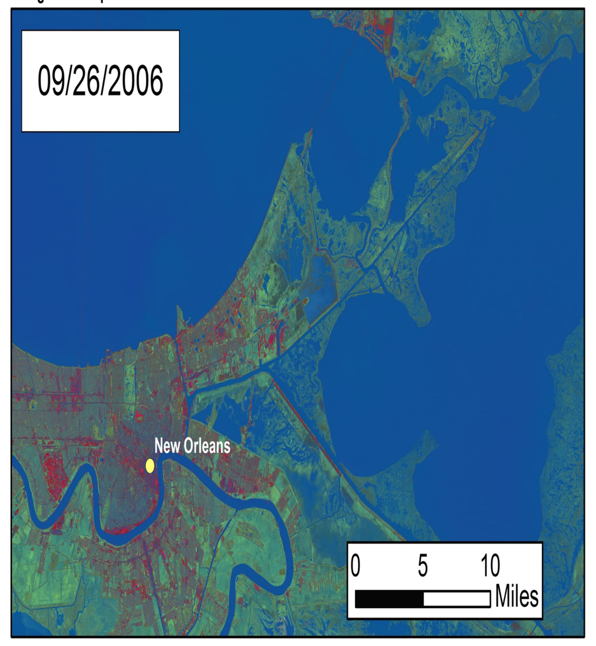


Figure 4d: Increase from 2006 in the reflectance in the red and green bands. This shows positive growth and development in vegetation and developed land, however the population growth does not appear to be what is was pre Katrina.

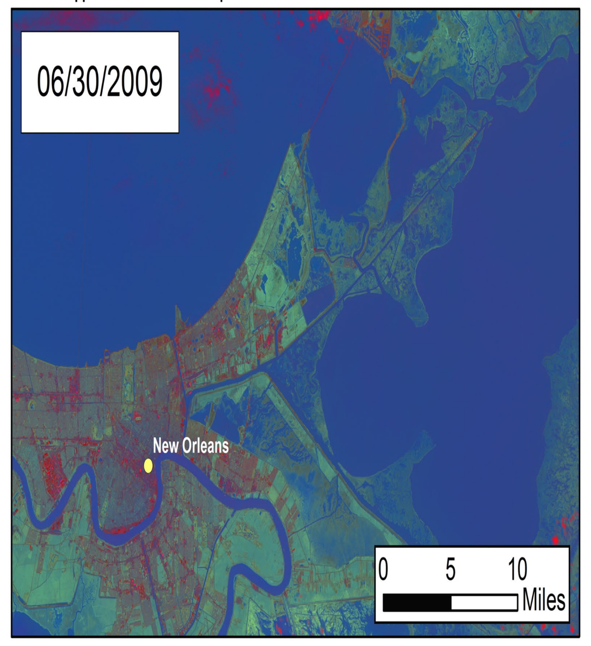


Figure 2: Map of Orleans Parish, LA. The blue pixels represent "Open Water" classifications in 2005. The red pixels show new areas that were classified as "Open Water" in 2006. This identifies possible areas that were subject to high amounts of flooding from Hurricane Katrina.

Figure 3a: Landsat image of Orleans Parish, LA before Hurricane Katrina. Residential areas are identified by having a grayish tone and healthy vegetation is identified as bright green.

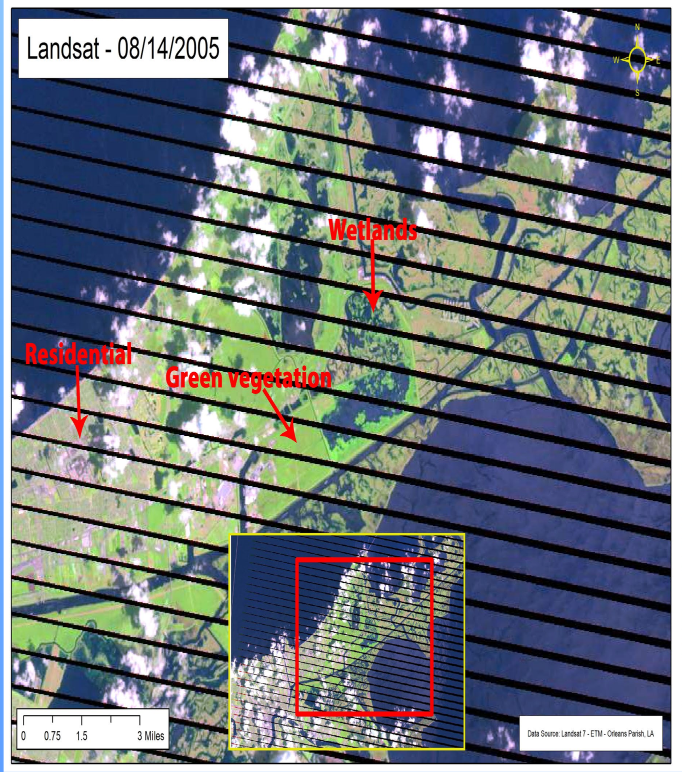


Figure 3b: Landsat image of the same area after Hurricane Katrina. Water from existing water bodies have flooded over into land. The vegetation that was once bright green is now dark green indicating that it has been overtaken by water.

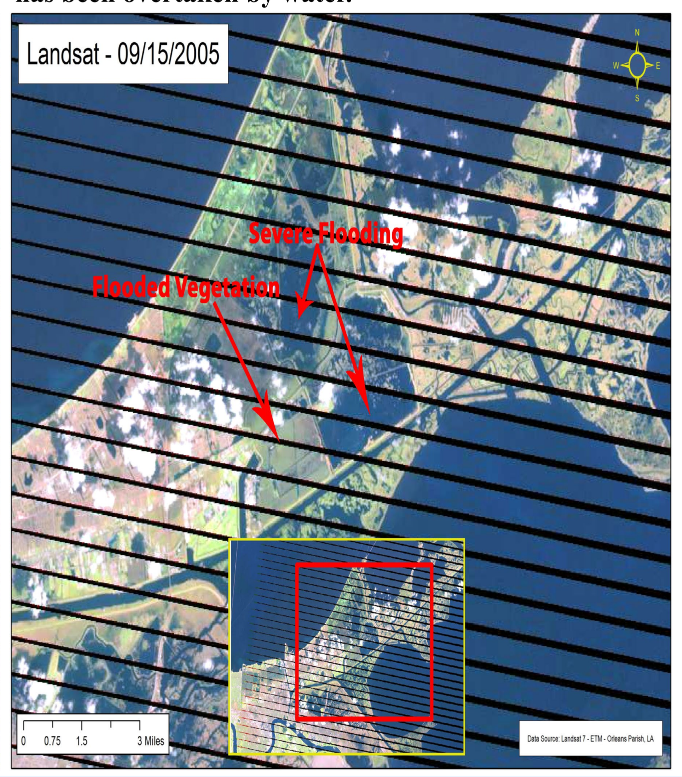


Figure 3c: One year later, during the rebuilding after Hurricane Katrina there are still pockets of flooding and bare land that at one point contained healthy vegetation.

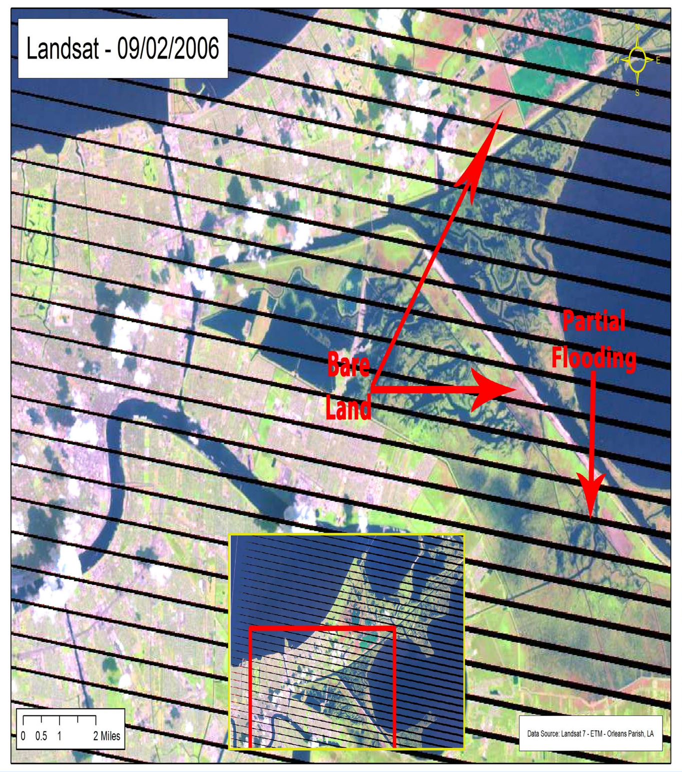
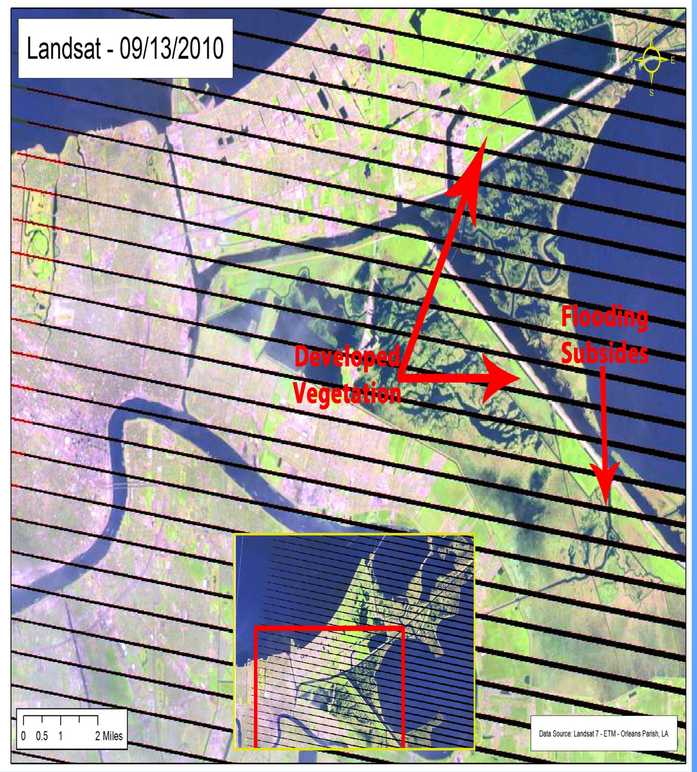


Figure 3d: Five years later, we see the land is more developed, bright green colors that were at once bare land are now healthy vegetation.



SOURCES OF ERRORS

Land classification data obtained from National Oceanographic and Atmospheric Administration (NOAA) Coastal Services Center (CSC)/Coastal Analysis Program(C-CAP) has an accuracy of 85%.

When acquiring the Landsat 7 ETM imagery, I tried to search for images around the same month when Hurricane Katrina occurred. The main problem I encountered was that the area had high amounts of cloud cover at this time period, so it was difficult to run analysis tools with the atmospheric interference. Another issue with the Landsat 7 ETM imagery was that there were scan lines that ran diagonally across the image. This was an instrumentation issue and not an error tied to a specific date because they occurred in all images I reviewed. Pixels that were part of the scan line were classified as having no data.

DISCUSSION

The primary purpose of this study was to calculate the impact of Hurricane Katrina based on studying landscape change through remote sensing methods. Three datasets were used in this study in order to see how each set of data correlates with proving the hypothesis. The first was pre and post Hurricane Katrina land classification data from the National Oceanographic and Atmospheric Administration (NOAA). Using this dataset I was able to utilize ArcGIS Spatial Analyst to perform raster math to see how certain land types have changed from 2005 to 2006.

The second dataset involved obtaining Landsat 7 ETM data to compare the impact Hurricane Katrina had on the landscape, and how it was rebuilt over time. This part of the study involved a large amount of visual interpretation between the different time periods. I was able to identify areas of flooding and the spectral effect of how healthy vegetation and flooded vegetation appeared over time.

Lastly, one important factor on the rebuilding progress is how the population changed over time. The method I chose was to analyze the thermal band reflectance using the Landsat MRLC/MTBS Reflectance sensor. While analyzing imagery for different dates I was able to ascertain that after the hurricane there was a substantial increase in the blue band reflectance and lower red and green band reflectance which would suggest high amounts of flooding in developed areas. Further analysis of the imagery years later indicates a positive growth of both population and vegetation.

CONCLUSIONS

The Coastal Analysis Program (C-CAP) data was critical in understanding the different land classification types and giving a quantitative assessment on how the landscape was affected by Hurricane Katrina.

Collecting Landsat data from different time periods offered difficulties due to cloud cover, because the shadows can resemble water which may lead to misinterpretations. Different bands of the electromagnetic spectrum were utilized to detect certain patterns. Through the application of Landsat 7 ETM, I have found that vegetation change is best used in the visible or near-infrared bands, while the thermal band in the Landsat MRLC/MTBS sensor offered a way of utilizing temperature to show population density.

A possible outcome from a study such as this would be that the information collected could be used by other government or local agencies to aid in their own Hurricane Katrina related studies.

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