The Impact of 2004 Hurricane Season on Beach Erosion in Volusia County, Florida

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Abstract:

This paper studies beach erosion as a result of 2004 hurricane season in Volusia County, Florida. Four hurricanes Charley, Frances, Ivan and Jeanne of category 2, 3, and 4 affected both coastlines of Florida during the year 2004. Multi-date Landsat TM data sets were used to analyze the changes in beach erosion from 1999 and 2004 along the coastline. The intent of this study is to quantify the amount of beach erosion and its impact on the economy of Volusia County. The beach in Volusia County is the prime tourist attraction generating in an excess of $3.3 billion in revenue per year. Not only is the beach vital for tourism but it also provides a nesting ground for sea turtles.

Introduction:

The majority of US population lives along the coast line. Florida's coastline is over 825 miles along the Atlantic Ocean on the Atlantic coast and the Gulf of Mexico. More than 409 miles of Florida's beaches are experiencing critical erosion. According to the Surfrider Foundation State Report 2003, critical erosion is defined as "A segment of shoreline where natural processes or human activities have caused or contributed to erosion and recession of the coastal system to such a degree that upland development, recreational interests, wildlife habitat, or important cultural resources are threatened or lost".

Florida has gone through a train of hurricanes Charley, Frances, Ivan, and Jeanne in a short period of six weeks in 2004. The State is currently experiencing hurricane fatigue hoping to dodge past the 2005 hurricane season unscathed.

The severe weather season started when Hurricane Charley came ashore at Charlotte County southwest of Florida on Friday, August 13, 2004, moved through central Florida to northeast and excited through Volusia County. It was a category 4 hurricane with 145 mi/h wind and 13-15 ft storm surge and left 27 dead. Because the storm tracked from west to east, Volusia County beach suffered little effect.

The second 2004 hurricane to hit Florida was Frances which formed in the Atlantic Ocean and made landfall on September 5, 2004 south of Cape Canaveral. It was a category 2 hurricane with wind speed of 105 mi/h, and left 18 dead. The impact of Frances was greater for Volusia County than Charley for two reasons: 1) the hurricane moved very slowly 5 mi/h staying close to the east coast for many hours, and 2) Frances was a monster in size, about size of Texas, more than 200 miles in diameter and affected the Florida Keys all the way to the coast of Georgia. The outer bands containing wind speeds of 60-80 mi/h kept lashing the east coast beaches and contributed to beach erosion not only in the Volusia County but the entire east coast. There were also 106 tornadoes attributed to Frances adding to the overall destruction.

Hurricane Ivan, the third to hit Florida that season, landed on September 15, 2004 just west of Pensacola, and east of Mobile at Gulf shore. It was a category 3 hurricane with wind speed of 130 mi/h, a 16 ft storm surge leaving 20 people dead in Florida. However, because of the Northeasterly movement, Ivan missed the study area completely.

The fourth major hurricane of the 2004, Jeanne, came ashore on September 25, 2004 almost the same place as Frances on southern Hutchinson Island. Jeanne was a category 3 Hurricane with wind speeds of 120 mi/h, and causing 6 deaths. The beaches were already vulnerable from Frances and could not withstand Jeanne which contributed to significant beach erosion in Volusia County. In certain areas it has left vertical sand cliffs 10-15 ft high.

Figure 1. Vertical Sand Cliffs, Volusia County, Florida

Most of the beach erosion experienced in Volusia County was caused by Frances and Jeanne. In all, Hurricane Frances destroyed or caused significant structural damage to 46 major structures along the coast of Volusia County. Hurricane Charley, caused extensive damage to 59 major habitable structures. Hurricane Jeanne destroyed or caused damage to 45 major structures as well as 19 seawalls (length of 5,430 ft). Approximately 150 dune walkovers throughout the county were also destroyed or damaged (Division of Water Resource Management, Bureau of Beaches and Coastal Systems, October 2004).

Beaches along the coastline were not spared the high winds (105 – 145 mi/h) lasting several hours, eroding beaches and destroying many homes, businesses and beach structures. Beach driving, an important part of tourism is now restricted due to beach erosion. The hurricanes stripped more than just sand from Volusia County's beaches. They whisked away $300,000 in toll revenue collected when drivers park on the beach during the 10-month toll season from February 1 to November 30 of each year.

Study Area:

Volusia County is located on the east coast of Florida, approximately 89 miles south of Jacksonville, 50 miles northeast of Orlando, and 60 miles north of the Kennedy Space Center. The Volusia County coastline consists of over 47 miles of narrow barrier island. The Atlantic Ocean is to the east, the Atlantic Intercoastal Waterway is northeast, and the Mosquito Lagoon is southwest. About 16.7 miles (Critical Erosion Areas Report, 2000) is contributing to or is in critical erosion before the 2004 hurricanes.

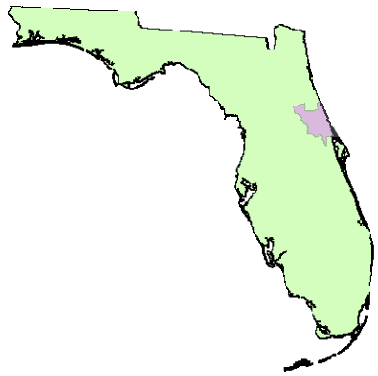

Figure 2. Volusia County, Florida

Volusia County Shoreline Change Rate:

There are two areas with high erosion rates within Volusia County (Taylor Engineering, Inc. 1999 and 2003). North of Ponce De Leon Inlet the erosion rate is about 16ft/yr based on 1993 – 97 shoreline analyses South of Ponce De Leon Inlet the erosion rate is about 9 ft/yr. These two locations are listed as critical erosion areas (Critical Erosion Areas Report 2000, DEP) and (Department of Environmental Protection, Florida).

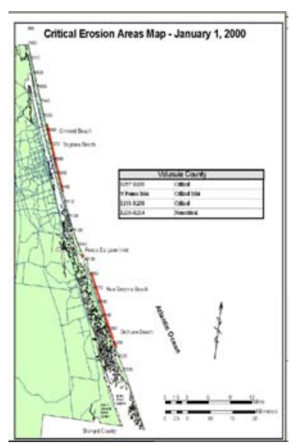

Figure 3: The red lines are critical erosion areas as well as has 16 ft and 9ft shoreline change rate.

One dredging operation was carried out in Ponce De Leon Inlet in 1999. The dredging was done at the north channel near the inter coastal walkway (IWW) intersection with 32,000 cubic yards of sand that was placed at the nearshore zone south of Ponce De Leon Inlet.

Geology of Beaches in Volusia County:

Volusia County beaches consist of primarily of fine grain quartz sand. In the northern and Southern parts of the county, the beach transitions to a red shell-quartz mixture, with steeper beaches consisting of mixed sand type (Foster and Cheng, 2000). When waves hit the beach, they suspend sand particles in the water. If the waves hit the shore at anything other than a 90 degree angle, part of the wave's energy is deflected parallel to the shore, creating a longshore rip current. The coarser-grained red shell material seems to move back onto the beach faster than the very fine-grained sugar sand that bleaches snow white in the central portion of the beach. That is a uniform-grained, finer silicate that's very easily suspended in a fluid and washed away (Joe Nolin, April 8, 2005). The finer-grain sand is lost easily and returns slowly, while the coarse-grained sand returns quickly, this variation can be explained from the size of the sand grain. Though the beach and fore dune are rebuilt, the erosion escarpment remains for a long time. Beach erosion can be measured through landward advance due to back beach erosion escarpment such as high water mark (HWM) or in terms of volume of sand lost. Volusia County's beaches are famous for hard beach driving but as a result of the 2004 hurricanes there is an increase in soft sand in some areas that were formerly hard packed. This makes driving difficult closing some areas until conditions improve.

Turtle Nesting:

There are number of wildlife habitats that utilize the coastal beach and dune system of Volusia County for feeding, shelter, and/or reproduction. Most significant of these are sea turtles. The four species are loggerhead (most common), Green sea turtles, Leatherback (the largest reaching up to 6 ft in length and weighing up to 1300 lbs.) and the Kemp Ridley sea turtle (the most endangered species). Kemp's Ridley has nested in Volusia County beaches only three times, since 1996. The nesting information from past years shows the lowest number of nests (204) for 1992. That number has increased for 2004 with 240 nests. There are 363 recorded nests for this year through August 25, 2005.

During the 2004 hurricane season, numerous nests were overwashed and nest barriers were either damaged or completely washed out (Annual Report of Volusia County Beaches Protected Species Monitoring Report, 2004). Hurricane Jeanne impacted the county's beaches with extreme high tides and heavy surf during the period from September 21 through September 27, with the storm's highest winds occurring on September 26th. By September 27, Jeanne had washed out all incubating nests that had survived Frances. Many nests were moved and relocated due to threat of tidal inundation.

Methodology:

Various methods have been used to analyze change in multi-date satellite imagery (Jensen, 1996; Furches, 2003; Levien, 1998; Millward and Piwowar, 2002; and Renzella, 2002). This study used two Landsat images in order to quantify the amount of beach erosion in Volusia County from 1999 to 2004. All image processing was performed using Leica Geosystems Erdas IMAGINE 8.7 software. Erdas IMAGINE is a complete geographic image handling application providing image processing, geographic image rectification and image visualisation for earth resource and mapping projects (Erdas Field Guide, 2003).

Satellite Imagery:

The data used for the study consists of two satellite images: Landsat 7 ETM 1999 image (courtesy of NASA distributed by Earthsat) and Landsat 5 TM 2004 image (distributed by Earthexplorer). These images were obtained from two different time periods, Landsat 7 ETM 28.5m dated October 23, 1999, and Landsat 5 TM 33m dated November 29, 2004. Figure 4 depicts the coastline of Volusia County, Florida, with the satellite images. The images are multispectral and multi-dated. They are displayed as false color composite. The band arrangement is 4, 3, and 2 assigned to channels red, green, and blue respectively. The two different resolution data were resampled to a uniform pixel size of 28.5 m.

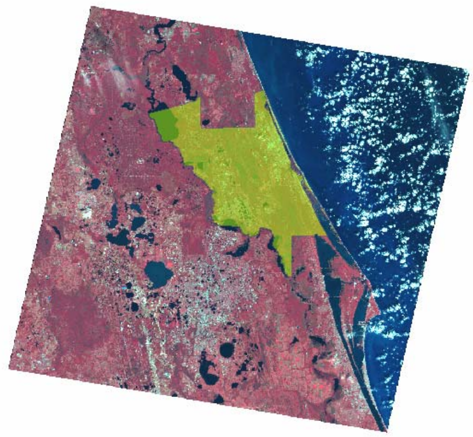

Figure 4. Landsat 5 TM dated November 29, 2004 with the outline of Volusia County in green.

Image Processing:

The two Landsat images acquired were from two different sensors; Landsat 5 TM and Landsat ETM. These two sensors have differing resolutions of 33m and 28.5m respectively.In order to get an accurate measure of change over time the resolutions of the two images had to be resampled to the same size. Therefore, the Landsat 7 ETM was resampled to 33m. Also, the Landsat 7 image had a better coordinate projection than the Landsat 5 TM, so the Landsat 5 2004 image was georeferenced to the Landsat 7 ETM 1999 image.

To increase the visual appearance of the imagery, special enhancement techniques were applied for better visual identification of land features. The linear contrast stretch function was used for tonal distinction between various features and a histogram-equalized stretch was applied.
Unsupervised classification or ISODATA (Iterative Self-Organizing Data Analyses) was used to classify or group similar pixel values. In this process, pixel groups are selected that represent patterns that are recognized or identified with the help from other sources. The iterations were set at 30 and the convergence threshold at 96. This repetitive process performs an entire classification and recalculates the statistics based on a minimum spectral distance formula to form clusters.

To aide in class identification, Digital Ortho Quarter Quads (DOQQ) were downloaded for 2000 and 2004 from Saint John Water Management. The DOQQs are one meter resolution and were used to help identify the classes from the unsupervised data set. From the ISODATA there were 70 classes which had to be identified and labeled. The few mixed classes (classes that combined one or more land features) were masked and reclassified. To create a mask, one mixed class is cut out of the original Landsat scene, then run through the ISODATA program. Each mixed class was reclassified into 6 – 30 classes based on the degree of mixed pixels and then all classes were appended together. These classes were repeatedly checked and rechecked for misidentified classes before the supervised classification process was run.

A supervised classification was performed on the data sets using the unsupervised class signatures as “training sets”. The supervised classification used a set of classes that was generated from our unsupervised classification. Using a combination of supervised and unsupervised classification can yield optimum results, especially with large data sets (e. g., multiple Landsat scenes) (Erdas Field Guide, 2003). The classes were then collapsed using a recode function to produce the final six classes. The final classification schemes were: Water, Surf zone, Urban, Marsh, All other vegetation, Sand and clouds (Landsat 2004 only).

All the classes were checked again for any misidentification. To smooth out the “salt and pepper” effect, a majority filter was applied to the supervised classification data files. The majority filtering function analyzes and modifies the classes for easier visual interpretation. Each pixel is analyzed with surrounding pixels determined by the size and shape of the filter specified. The center pixel value is replaced or remains the same by the filtering function. The neighborhood definition for this study used a 3x3 pixel window. In this operation a moving window is passed through the classification data set and the majority class within the window is determined. If the center pixel is not the majority class, its identity is changed to the majority class, if not than the identity of the center pixel remains unchanged. At this point the classes are evaluated again for accuracy.

To allow for discrepancies caused by the software underestimating the area of our critical class (the surf zone), a buffer was generated. This surf zone class includes both back and forebeach and due to dune vegetation it was determined our surf zone area was underestimated The surf zone class was recoded and neighboring pixels were assigned a value based on their Euclidean distance from the selected pixels (surf zone) that creates a buffer zone around this area. The distance to search is just one pixel (30m). After the search image was analyzed, it was recoded.

To check the validity of the final classified image, an accuracy assessment was carried out using equal random points for five classes (excluding water) to assess the quality of the classification. It is very important as it shows the errors that will be multiplied when the images are compared by change detection method. The classified images show above 90% accuracy (Table 1).

Table 1: Accuracy Assessment

50 Random Points	**1999**	**2004**
Overall Classification Accuracy (6 classes)	94%	90.24%
Overall Kappa Statistics	0.9151	0.8719

To determine the amount of beach erosion from 1999 to 2004, the surf zone class was used for a change detection analysis. Change detection is a common procedure using remotely sensed data to study the amount of change or difference an area over time.

The surf zone class is isolated for the change detection analysis. The change detection was run on the continuous data of the original Landsat imagery. Change detection calculates change in brightness values of the imagery overtime. The image difference file is the direct result of subtraction of the “before” (1999) image from the “after” (2004) image. This difference then generates a highlight change file which shows the decrease and increase in the area of interest (our surf zone class).

Results and Analysis:

The change detection is compared between1999 and 2004. The change detection results are shown in Figure 5. The red area in Figure 5 indicates the decrease in the surf zone while the green area shows the increase in surf zone. Table 2 indicates a significant change in the surf zone after 2004 hurricanes. The area of surf zone has moved inland, sand has decreased, and urbanization has increased, from 1999 to 2004.

The green area could be a false "increase" in the beach area. It seems the sand dunes may have partially eroded interpreted as an "increase" in sand area by the software. Ground truthing" will confirm the interpretation of these results. Table 2 indicates a significant change in the surf zone after 2004 hurricanes. The area of surf zone has moved inland, Sand has decreased, Urbanization has increased, from 1999 to 2004.

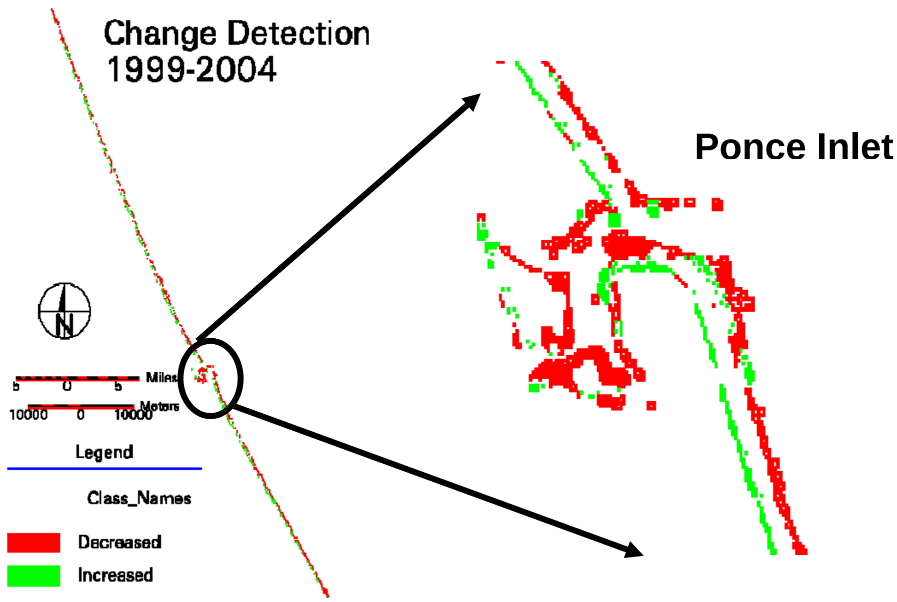

Figure 5. Change detection 1999 – 2004, with a close up of Ponce De Leon Inlet

Table 2: Change Detection

Area in Sq. miles	1999 - 2004
Decreased	2.87
Increased	1.04
Net Change	1.83

Conclusion:

The change detection data suggests the surf zone has moved inland and the beach area has decreased. This data confirms the results from Volusia County's preliminary report on beach impact from the 2004 hurricanes. Three areas South of Ponce De Leon Inlet, south of Flagler County and Daytona Beach shore line shows more beach erosion in the change detection of 1999 and 2004 images. These results are similar to the findings in Critical Erosion Areas Report.

Most of the beach area is flat with a large horizontal tide range. This area experiences large seasonal beach width changes. The sand seems to give high reflectivity affecting sun glare in the images which makes it difficult to distinguish urban area with and the sand zone. Plus frequent high wave conditions cause run up on the flat beaches. All these factors pose difficulty in identifying and assigning accurate classes. However, the change detection methods employed here are quite successful at highlighting significant changes in beach erosion for this study area.

Work is already beginning moving 800,000 cubic yards of sand from Rattlesnake Island along six miles of New Smyrna Beaches. The cost is estimated to be $6 to 8 million dollars. The sand will be pumped and placed in a dune design along the beach, from Sapphire Road south to sandpiper condominiums, just north of Angelfish Avenue (Stawicki, Melanie, Feb 10, 2005). The data produced in this study will aide Volusia County managers in a Decision Support System to place the sand in both a strategic and cost effective manner.

Beach and dune loss has affected the sea turtle nesting in Volusia County. The Volusia County Environmental Management Turtle Journal has reported the amounts of good nesting habitat on county beaches are severely reduced due to erosion from the 2004 hurricanes. In 2004 the total number of nests was only 240, which is below average (Ecological Associates, Inc., Jenson Beach, Florida, 2004). The Sea Turtle Monitoring Program of Volusia County had restored many nesting barriers. They also relocated the nests that were laid in low areas or were in danger of washing out. According to Sea turtle report 2004 the six week period of hurricanes had affected the nesting of sea turtles. Sea turtles normally lay eggs in dry sand; hence due to a long wet period the nesting was very low. In addition the incubation period and hatching of nests were longer. The 2005 nest numbers are much impressive and shows that turtle monitoring program is effective and has come over the hurdle of washed out sand dunes.

This study has only measured the surf zone for beach erosion. In addition to the surf zone, sand area and sand dunes will also be included in future research work that may contribute towards more accurate and complete results. Plans also include future analysis of 2005 Landsat for the same area to measure the effects of 2005 storm activity that may be contributing to more beach erosion.

Acknowledgements:

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