MULTI-TEMPORAL CHANGE DETECTION ANALYSIS OF BEACH EROSION USING SATELLITE REMOTE SENSING

Valentina S. David*

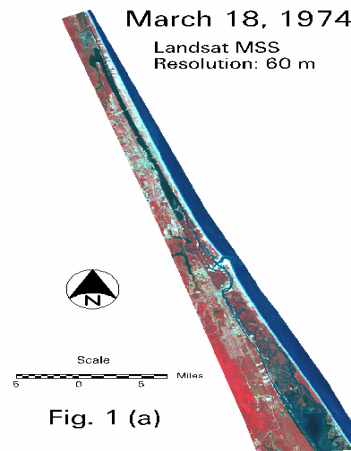Bethune-Cookman College, Daytona Beach, FL

Introduction: Majority of US population lives along the coast line. The residential and commercial development in these areas leads to beach erosion and also become dangerous for plant and animal life around beach and in ocean. Florida's coastline is over 825 miles along the Atlantic ocean on the East coast and Gulf of Mexico on the West coast. More than 409 miles of Florida's beaches are experiencing critical erosion. According to 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".

Volusia County coastline is over 44.5 miles (70 km) and about 16.7 miles (Critical Erosion Areas Report) is contributing to or is in critical erosion area. Many factors contribute to beach erosion such as hurricanes, tropical storms, human activities, beach driving and development activities. Volusia County beaches primarily have fine grain quartz type of sand. In the northern and Southern parts of county, there are transitions to beaches composed of a shell-quartz mixture, with steeper beaches of the mixed sand type (Foster and Cheng, 2000).

To some extent during storm the sand eroded to offshore normally is returned and the beach is rebuilt during the calmer periods of swell waves.
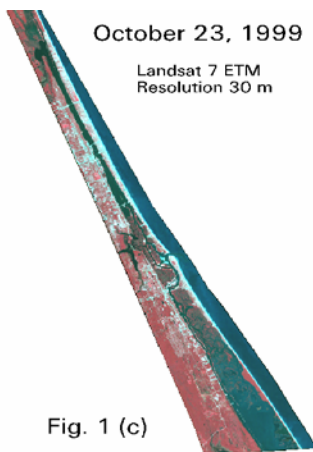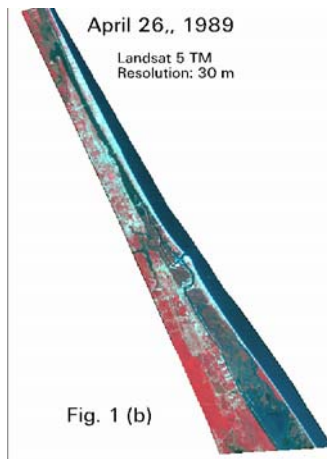
Though the beach and fore dune are rebuilt, but the erosion encarpment remains for a long time. Beach erosion can be measured through landward advance due to back beach erosion encarpment such as high water mark (HWM) or in terms of volume of sand lost.

Various methods have been used to analyze change in multi-date change analysis (Jensen, 1996; Furches, 2003; Levien, 1998; Hayes and Sader, Millward and Piwowar, 2002; and Renzella, 2002). Here remote sensing technique has been used to obtain the Satellite images and analyze for beach erosion. This paper we report the study of Volusia county, Florida coastline for beach erosion over 25 year period.

Fig. 1 (a)

---

*Valentina S. David
 640 Dr. M. M. Bethune Blvd.
 Bethune-Cookman College
 Daytona Beach, FL 32114 - 3099

April 26,, 1989

Landsat 5 TM
Resolution: 30 m

Fig. 1 (b)

October 23, 1999

Landsat 7 ETM
Resolution 30 m

Fig. 1 (c)

Satellite Imagery: The images in Fig. 2 represents the coastline of Volusia county, Florida. These images are obtained from three different satellite sensors and form a 25 year chronology. The images are multispectral and multi-dated (Fig 2 a, b, and c). All are displayed as false color composites. The band arrangement is 4, 3, and 2 assigned to channels red, green and blue respectively. Fig 2 (a) imagery is a MSS 60m dated March 18, 1974, (b) is a Landsat 5 TM 30 m dated April 26, 1989, and (c) is a Landsat 7 ETM 30 m dated October 23, 1999. Normally different resolution data needs resampling of images to a uniform pixel size. Here imagery used has different pixel size and no resampling has been performed.

Spatial enhancement was used for better visual identifications of pixels. Linear contrast stretch function was used for tonal distinction between various feature. Histogram-equalized stretch was also performed.

Methodology:
Erdas Imagine 8.7 was used to study the change detection for beach erosion. Change detection is a common procedure in remotely sensed data to study the differences between two dates. Here we are using three dates to study these changes. Images first were visually compared for differences. Two images at a time were overlaid in imagine viewer and using the swipe tool were compared visually and the changes were noted down. This helped in identifying the various area of interest. Even different band combinations (Quinn 2001,6) such as natural color 3, 2, 1 (R, G, B) for sediments in water and urban regions, 4, 5, 1 (NIR, MIR, B) for vegetation and importantly 7, 5, 4 (FIR, MIR, NIR) combination to define coastlines and shores are used to get a close look at these differences.

Next classification was used to classify similar pixel values in a group and give it a name. In this process, pixels are selected that represent patterns that are recognized or identified with the help from other sources. Unsupervised classification was used to identify the following classes, Water, Surf zone, Urban, Marsh-Vegetation, All other vegetation, and Sand classes. "Iterative Self-Organizing Data Analysis Technique (ISODATA) algorithm was used here. The iterations are set at 30 and convergence threshold at 95. It repeatedly performs an entire classification and recalculates the statistics based on minimum spectral distance formula to form clusters. There were 50 classes and each was identified based on the reflection value and named as six classes mentioned above. Few mixed classes were masked and reclassified into 5-20 classes based on the degree of mixed pixels. To create a mask one mixed class is cut out of the original image by selecting the original Landsat scene and than the recode was set to 1 for the mixed class and all other classes to o. The output mask file has pixels of only the mixed class. The unsupervised classification was performed on the mask scene. When all the mixed classes are reclassified they are appended together. Repeatedly these classes were checked and rechecked for misidentified or misclassified classes before Supervised classification process is run. Supervised classification identifies pixels with similar characteristics from the signature of the unsupervised classes. The potential recognized class calculates the statistics from these pixels to

create a parametric signature of the class. All the classes were checked again for any misidentification. The majority filter process was run to smooth out the pixels. In this operation a moving window is passed through the classified data set and the majority classes 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 the same. In 1974 image the bridges had gaps after running the 3x3 majority filter. The specific class for bridges was identified and was excluded in the majority filter rerun.

Majority filtering function analyzes and modifies the classes to give a better look. Each pixel is analyzed with the pixels in its neighborhood and determined by the size and shape of the filter specified the center pixel value is replaced or remains the same by the filtering function. Here 3x3 neighborhood definition size is used. At this point the classes are evaluated again to get the desired results.

Here the surf zone class is the area of interest. The surf zone class is recoded and neighboring pixels are then 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. After the search image is analyzed, it is recoded. While recoding the buffer class was set to 50 and all other classes to o. Than all the classes were indexed. This process adds the two thematic layers together to create a composite layer and identify the classes and run a final recode so the raster attributes have only six classes.

Accuracy assessment was carried out to assess the quality of the classification. Accuracy Assessment allows you to evaluate a classified thematic raster layer. The cellArray for this utility lists two sets of class values for the randomly selected points in the classified image file. One set of class values is automatically assigned to these random points as they are selected, and the other set of class values is input by you. These reference values should be based on ground truth data, previously tested maps, aerial photos, or other data. The accuracy Assessment CellArray is an organized way of comparing the classification with ground truth data etc.was carried out to assess the quality of the classification. All three classified images show above 90% accuracy (Table 1).

The change detection and matrix analysis are compared between: (i) 1974 and 1989 images, (ii) 1989 and 1999, and (iii) 1974 and 1999.

The Matrix enables you to create an output file that contains classes that indicate how the class values of the input files overlap.

The surf zone class is isolated for change detection. The change detection was run on a continuous data. Change detection is used here to compute the differences between two images at a time and highlights the change that exceeds the specific threshold. Change detection calculates change in brightness values overtime. The image difference file is the direct result of subtraction of the before image from the after image. The highlight change file gives the decrease and increase in the area of interest.
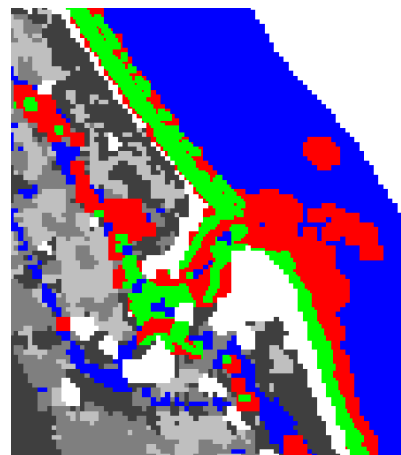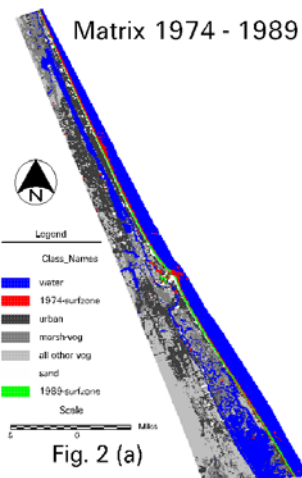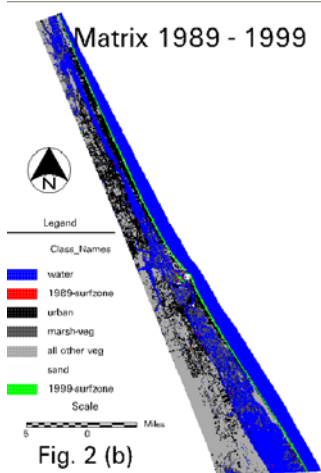

Fig. 2 (a)

Fig. 2 (a): Ponce Inlet at New Smyrna
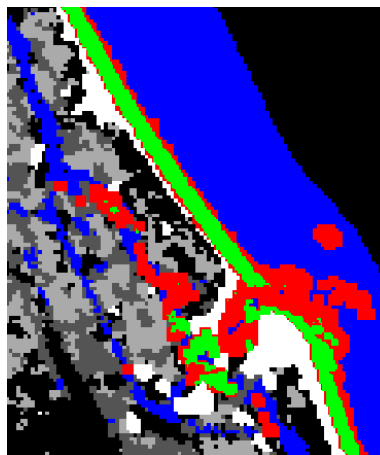
Fig. 2 (b)

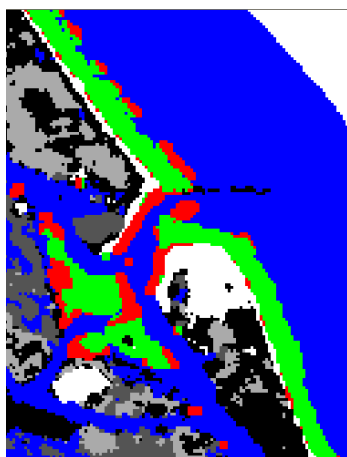Fig 2 (c): Ponce Inlet at New Smyrna
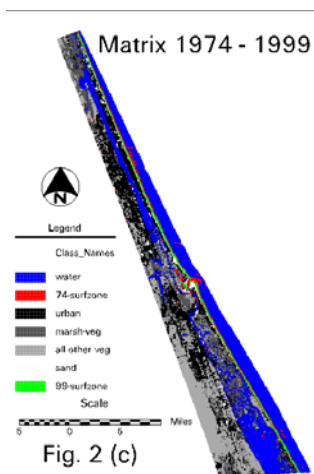

Fig. 2 (b): Ponce Inlet at New Smyrna

Fig. 2 (c)

Results and Analysis: Visual comparison of images shows that in 1974 the intercostals water look more clearer, the Ponce Inlet is narrow, where 1989 has more urbanization which increased in 1999 and the inlet is so much wider.

The change detection Fig. 2, Table 1 and Matrix analysis Fig. 3 shows a significant change in the surf zone in 1989 where as there is little change in 1999. The results from the two methods are comparable. Area of surf zone has moved inland, Sand has decreased, Urbanization has increased, and change is more apparent in 1989.

Table 1: **Change Detection**

Area in Sq. miles	89-74	99-89	99-74
Decreased	6.85	0.95	5.67
Unchanged	1107.81	1112.7	1108.92
Increased	1.2	2.21	1.28

Change Detection = 1989 - 1974

Legend

Class_Names

■ Decreased
■ Increased

Scale

5   0   5   Miles
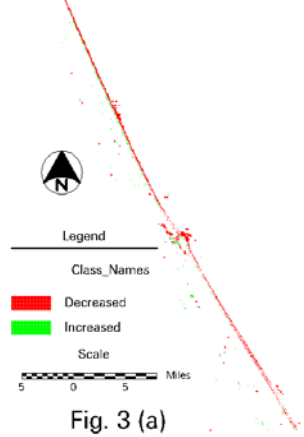
Fig. 3 (a)

Fig 3 (b): Ponce Inlet at New Smyrna

Change Detection = 1999 - 1974

Legend

Class_Names

■ Decreased
■ Increased

Scale

5   0   5   Miles
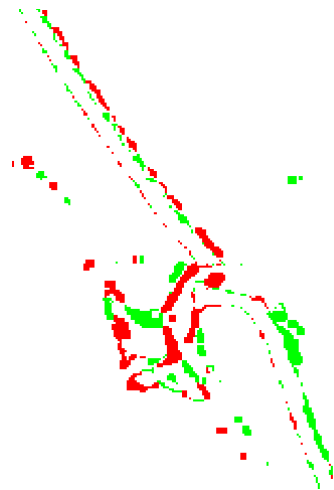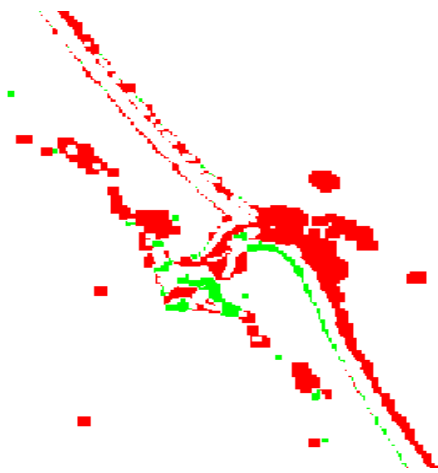
Fig. 3 (c)

Fig. 3 (a): Ponce Inlet at New Smyrna

Change Detection = 1999 - 1989

Legend

Class_Names

■ Decreased
■ Increased

Scale

5   0   Miles
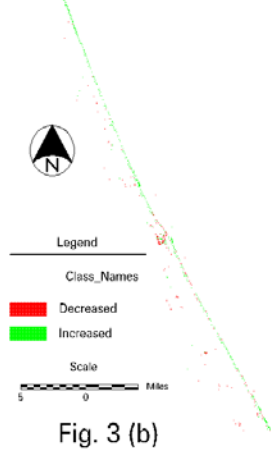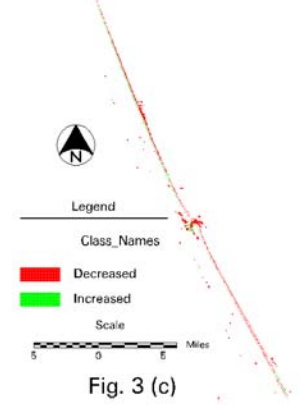
Fig. 3 (b)

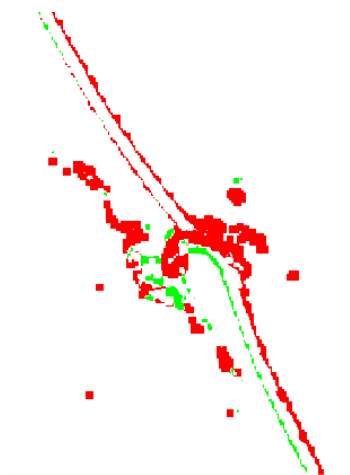Fig. 3 (c): Ponce Inlet at New Smyrna

Discussion:

The change detection and matrix analysis shows that the area for surf zone has moved inland and sand has decreased. This change is more apparent in 1989 than in 1999. There are three possibilities for this change. Firstly, the 1988 Thanksgiving storm which was Northeasterly and lasted several days may have left its long lasting impact. These winter storms or Northeasters are known to occur with greater frequency and thought to have a greater impact on shoreline change than hurricanes. Secondly, the time interval of the data used for matrix analysis is not uniform (Beach Erosion Control Program). The first time interval is of 15 years (1974 – 1989), where the second interval of time is only 10 years (1989 – 1999). Thirdly, in 1986 Florida Legislature adopted a Comprehensive Beach Management Program (Beach Erosion Control Program (BECP)). The program was established to evaluate and recommend the viable solutions for beach erosion control and restoration. The change in 1999 is not very apparent, that can be explained by the beach nourishment program which is very active to this date.

Most of the beach area is flat and has 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 identify the urban area with high buildings and the sand zone. The frequent high wave conditions causing run up on the flat beaches. All these factors pose difficulty in identifying and assigning accurate classes.

Conclusion:

The Beach control program seems to be effective as the results do not reflect change in surf zone in 1999. The methods employed here for change detection are quite successful at high lighting significant changes in this capacity. The winter storms and urbanization along the beach is also affecting the surf zone.

References:

1. Beach Erosion Control Program (BCEP), Florida, Department of Environmental Protection, http://www.dep.state.fl.us/beaches/programs/bcherosn.htm

2. Critical Erosion Areas Report, Department of Environmental Protection, Florida, http://www.dep.state.fl.us/beaches/publications/pdf/eroar-ne.pdf

3. Emmett R. Foster and Jenny Cheng, Shoreline Change Rate Estimates, Volusia County, Report No. BCS-00-04, Florida Department of Environmental Protection, Office of Beaches and Coastal Systems, December 2000.

4. Furches, Corey, 2003, Change detection For Baltimore Maryland (1984-1997), Using Image Information with Landsat Thematic Mapper Imagery, http://www.geo.wvu.edu/geog655/spring2002/03/project.htm

5. Hayes, Daniel J., Sader, Steven A., Change Detection Techniques For Monitoring Forest Clearing and Regrowth in a Tropical Moist Forest.

6. James W. Quinn; Band Combinations, 2001, http://web.pdx.edu/~emch/ip1/bandcombinations.html

7. Jensen, J, R., 1996, Introductory Digital Image Processing: A Remote Sensing Perspective (2nd ed.)., Upper Saddle River, N. J. Prentice-Hall.

8. Levien, Lisa M., et. al., 1998, Statewide Change Detection Using Multi-Temporal Remote Sensing Data, First International Conference on Geospatial Information in Agriculture and Forestry, Lake Buena Vista, Florida.

9. Millward, Andrew A., Piwowar Joseph, M., 2002, Exploring Ordination as a Method for Normalizing Dispartate datasets: Implications for Digital Change Detection, Symposium on Geospatial Theory, Processing and Applications, Ottawa.

10. Renzella, Brian, 2002, Multi-Temporal Change Detection Analysis of Wheeling West Virginia Using Manual Image Interpretation and Post-Classification Comparison, http://www.geo.wvu/geog655/spring2002/09/project.htm

11. Surfrider Foundation State Report, 2003, Florida Beach Erosion, http://beach.com/stateofthebeach/6-state/beach_erosion.asp?state=FL