Shoreline Changes and Characterization of Sediment Facies in Cabo Rojo Puerto Rico Using Remote Sensing Techniques

Joanna C. Cepeda Díaz[1] and Ann M. Jiménez[2]

[1] Department of Geology, University of Puerto Rico – Mayaguez; e-mail: cristinaaaaa@hotmail.com
[2] Department of Electrical Engineering, University of Puerto Rico – Mayaguez; e-mail: ann_marie_jimene@hotmail.com

Abstract – Remote sensing is a valuable tool for quantifying coastal erosion and the different factors that cause it. Applied correctly, it may lead to future solutions, starting by the identification of potential off-shore sand deposits that might be used for beach replenishment. In Cabo Rojo, Puerto Rico, the erosion rate for a period of 12 years was as high as 1.88 millimeters per year. An attempt to process an IKONOS satellite image of the area failed due to image preprocessing problems, but image classification show differences in digital values in the different spectral classes. This may indicate different sediment facies distribution, never forgetting that field data is extremely important for verification.

INTRODUCTION

Beach environments surround the island completely and its balance should be of great concern. In Puerto Rico, human activity has a major effect on the coast, especially construction (housing and coastal structures) and sand dune extraction. Finding potential near-shore and off-shore sand sources may lead the way to finding a solution for beach erosion (beach replenishment).

Remote sensing techniques to study shoreline changes and beach sand potential sources may prove useful, especially in areas where sample collection may not be viable It is a valuable tool that can provide information about lithology and structure, and it can allow identification of changes (sea level and shoreline) and definition of patterns in dynamic environments, such as coastal regions. Applied correctly, it may aid in protecting such areas when it comes to decision making.

MATERIALS AND METHODS

A. Shoreline Changes

ESRI® ArcMap™ version 8.2 was used to georeference the aerial photographs.

Aerial Photographs from 1987 and 1999 of the Combate area were used at a scale of 1:5000. Deneba Canvas version 8 was used to calculate shoreline changes in position.

The shoreline was outlined on both aerial photographs and then put one over the other to quantify changes due to erosion or accretion. The lines were then divided into transects of .63 inches, which in real scale represents a distance of 80 meters. Polygons were used in each transect to calculate the area, which represents the change in shoreline. The area was reported in millimeters (mm).

B. Image Preprocessing

An IKONOS satellite image for the Cabo Rojo area was provided by the PaSCoR lab in UPRM. The program used to process the image was ENVI (Environment for Visualizing Images) version 3.5.

The image had to be preprocessed before multispectral analysis. This includes rectification, masking, calibration, and atmospheric correction (Barreto et al 1998). The rectification procedure was already performed prior to image acquisition. Masking is the definition of the land and ocean boundary using the IKONOS spectral band MS-4 (near infrared).

Calibration is performed using an algorithm to change raw data to radiance values. The calibration coefficients for IKONOS are determined by the equation: $L_k = \int L(l)R_k'(l)\,dl$ (1), where: L_k = in-band radiance at the sensor aperture for IKONOS band k (mW/cm^2-sr); $L(l)$ = spectral radiance at the sensor aperture (mW/cm^2-sr-mm); $R_k'(l)$ = peak-normalized spectral response for IKONOS band k; and l = wavelength (mm) (Space Imaging, 2003). The calibration preprocess was not performed to the IKONOS image because ENVI does not provide a

calibration utility for this satellite's images.

The corrections for atmospheric local conditions was performed using the dark subtract function in ENVI. This function subtracts the minimum band value to all the other digital values assuming that the minimum value is the atmospheric contribution to the digital values in the image.

C. Image Processing

Multispectral analyses of IKONOS satellite images will be used to describe bottom sediment facies in foreshore and nearshore areas. IKONOS has four spectral bands (blue, green, red, near infrared) with a spatial resolution of 4m and one panchromatic band with a spatial resolution of 1m. The image has a spatial resolution of 1m due to a merge with the panchromatic band. (Space Imaging 2003).

The spectral bands used are located between the visible and near infrared ranges (MS-1 (blue), MS-2 (green), MS-3 (red), MS-4 (near infrared)) because their combination penetrates shallow water. MS-1 (blue) was be used to analyze bathymetry, bottom sediment facies and sediment distribution. MS-4 (near infrared) was used to delineate water bodies.

Radiance value distribution was supposed to be used to distinguish among sediment types. A prior study determined that carbonate sands tend to have a higher radiance value, mixed sands have a lower value, and no-radiance values could be associated with possible hard grounds (Morelock et al 2002). Radiance values were not obtained because the calibration preprocess was not performed. Instead, digital values were reported.

An unsupervised isodata classification was performed on the MS-1 band A supervised parallelepiped classification was also performed using eight regions of interest. Digital values for each spectral class were reported.

RESULTS

A. Shoreline Changes

Table 1: Shoreline change per transect

Transect	Shoreline Change (mm/yr)
1	1.89
2	10
3	10
4	10
5	10
6	10
7	10
8	10
9	10
10	10
11	0.67
12	0.67
13	0.67
14	0.67
15	0.95
16	0.67
17	0
18	0.95
19	0.67
20	0
21	0
22	0
23	0.67
24	0
25	0.67

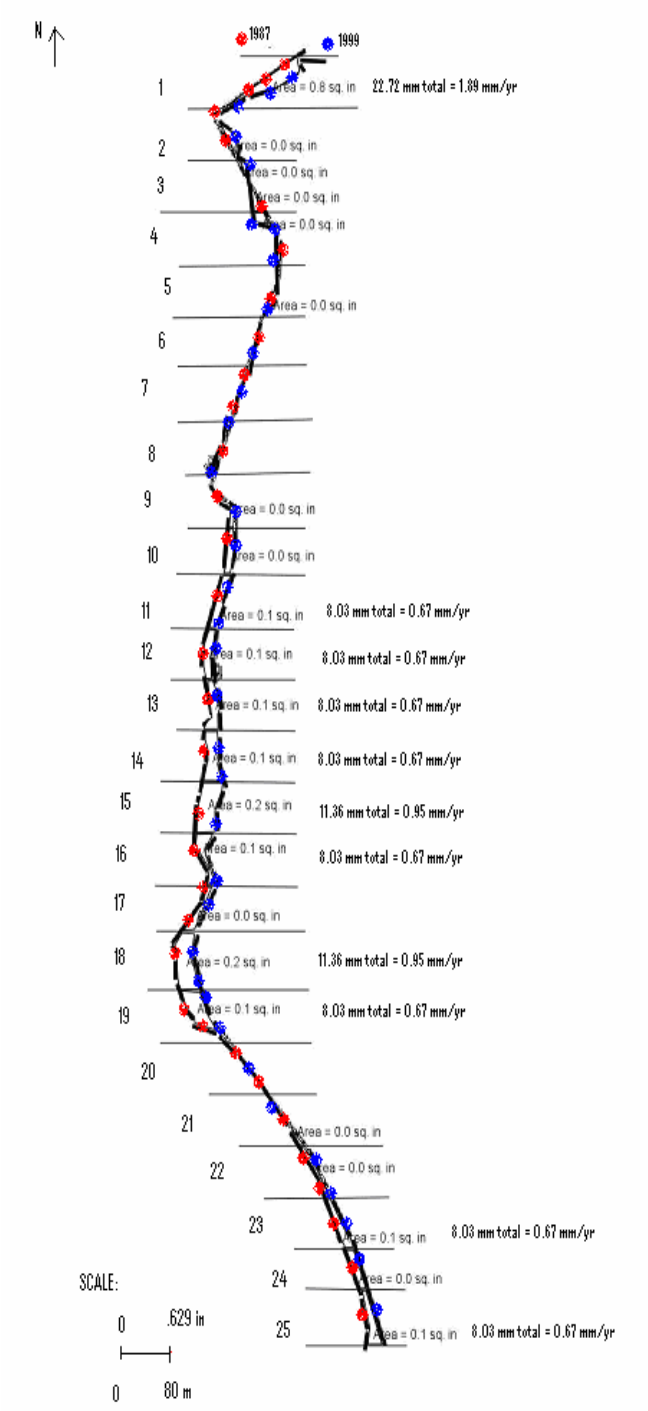

Figure 1: Shoreline outlines. The photographs were blown up to a scale of 1:5000. One inch in the photograph represents five thousand inches in real scale. (1 in = 0.0254 m; 80 m = 3,149.6062992 in (real scale); 80 m = .629 inches (Aerial Photo)).

B. Image Processing

Figure 2: Rectified and atmospherically corrected IKONOS Satellite image of Cabo Rojo, Puerto Rico.

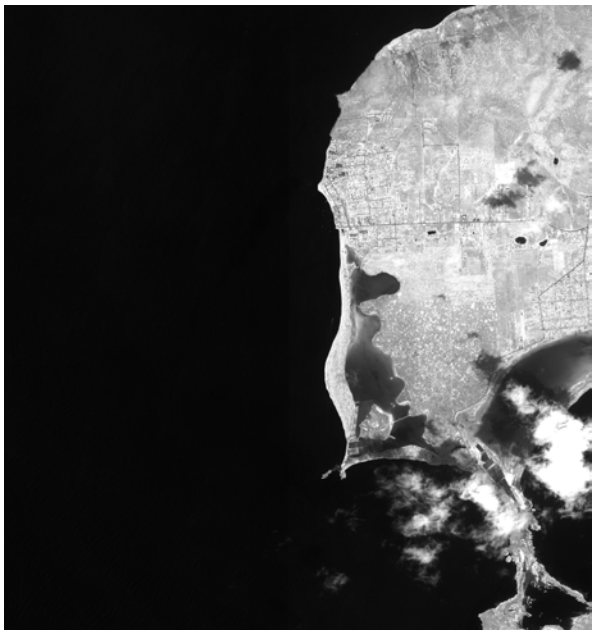

Figure 3: Masked IKONOS Satellite Image

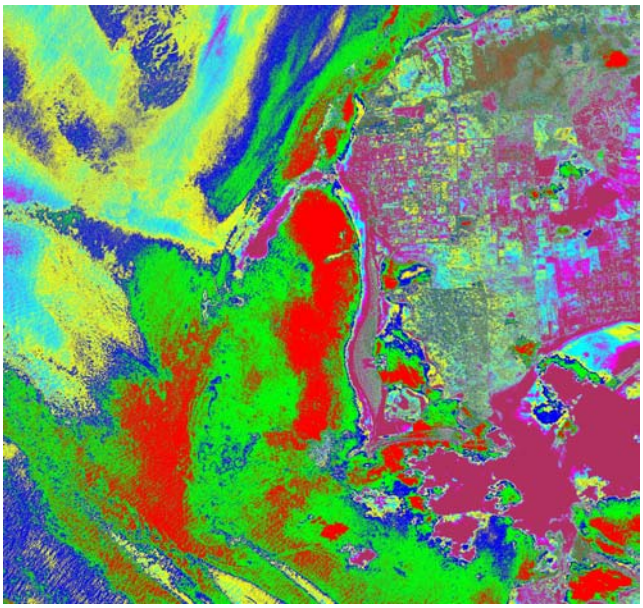

Figure 5: Unsupervised classification (Band MS-1)

Table 2: Class distribution and digital value for unsupervised classification

Class Name	Npts	Pct	Digital Value
Class 1	[6211737]	12.12%	0
Class 2	[11660711]	22.75%	49
Class 3	[8723895]	17.02%	80
Class 4	[10051635]	19.61%	18
Class 5	[6207253]	12.11%	90
Class 6	[2587745]	5.05%	47
Class 7	[5819584]	11.35%	153

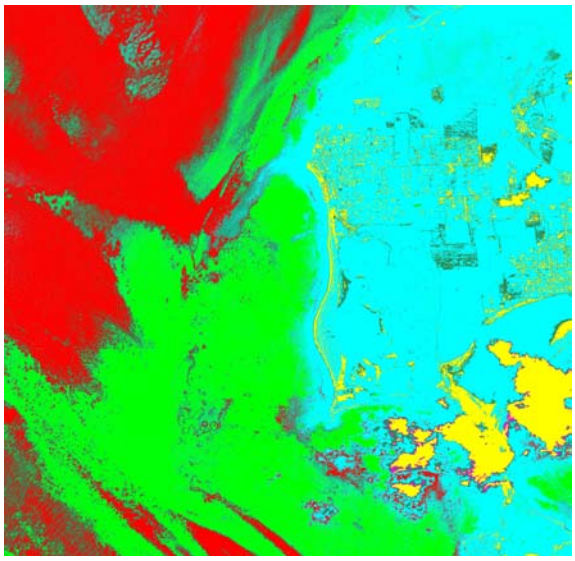

Figure 7: Supervised classification (Band MS-1)

Table 3: Class distribution and digital value for supervised classification

Class Name	Npts	Pct	Digital Value
Region #1	[11007709]	21.47%	61
Region #2	[12949918]	25.26%	17
Region #3	[2515458]	4.91%	255
Region #4	[18995819]	37.06%	101
Region #5	[154725]	0.30%	45
Region #6	[5638931]	11.00%	140

DISCUSSION

Comparison between aerial photographs of 1987 and 1999 in the Combate area show that there has been a great loss of shoreline due to erosion. This may be a result of coastal construction (e.g. housing, man-made structures), wave and current action and storms (e.g. Hurricane Georges in the late 1990's). The most affected area is the northernmost part of the studied area. An erosion rate of 1.88 mm/yr was calculated.

Other areas show no change, meaning that there is a balance between erosion and accretion rate. Some of those areas do have small irregularities, but proved insignificant to the measurements performed. A more precise scale might quantify more specifically those irregularities.

As for the satellite image analysis, both unsupervised isodata classification and supervised parallelepiped classification show different class distribution. After the selection of regions of interest to perform a supervised classification, there are noticeable numerical differences between classes. Since the relation of digital values to radiance is unknown due to failure due to problems with the calibration procedure, no discrimination for sediment facies could be made.

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LITERATURE CITED

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