Monitoring Shoreline Change in Playa Jayuya, Fajardo Using Remote Sensing Techniques

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ABSTRACT- Coasts are dynamic environments were a high percent of the world's population are concentrated. In this study shoreline change is analyzed by distinct remotely sensed methods from ENVI and QGIS. A combination of aerial photography from 1930, 1950, 1987 and a satellite image of Landsat ETM+ of 2000 were selected for the shoreline change analysis of playa Jayuya. Edge detection was used to evaluate changes in playa Jayuya. Results showed that erosion increased rapidly since 1950 to 2000. Better methods are required for accuracy estimations of shoreline changes.

KEYWORDS- coastal geomorphology, remote sensing

INTRODUCTION

Shorelines are dynamic environments constantly changing. Coastal areas are subject to a variety of phenomena, such as sea level variations, storm surges, wave energy, tidal inundation, tectonics and land subsidence, sediment budget changes, human activities that continually modify and play fundamental roles in coastal development and exposed to erosion (Aiello et. al. 2013).

A recent study by Jackson et al. (2012), stated that to be able to gain a better understanding of the processes that impact coastal resources and determine their vulnerability there needs to be a focus on mapping and quantifying the movement of the shoreline. In Puerto Rico almost 61% of the population lives in coastal areas, however most of shoreline researches in the island are either from the north or west coast. Studying this site is important not only because it is constantly changing due to natural process, but because it has an archeological site that has valuable historical information of Puerto Rico. Pre-historic archeological (600 B.C,) materials such as ceramic vessels and bones are found in the sand of playa Jayuya. Since coastal erosion is increasing, the archeological material is being lost or is trapped in the beach rock. Even though coastal erosion is a natural process, it is a risk factor in this particular area, because of the valuable historical information it contains.

To evaluate shoreline change different techniques are used which include shoreline tracing of aerial photograph and other remote sensing analysis to identify shoreline change on island and atoll island (Ford, 2011). Maiti (2009), used satellite images to measure and predict shoreline change, these technique are challenging due to different time ranges or meteorological conditions that cause problems during data acquisition. On the other hand the morphological characteristics provided by satellite images facilitate the identification of the predominant process causing the evolution of the beach. Shoreline changes studies use several proxies in order to determine changes in the coastline, such as

low or high water level, dunes, structures or vegetation.

Ford (2011) used the edge of the vegetation as proxy because it is relatively easy to identify in imagery. Shoreline position can be study using geographic information techniques such as Digital Shoreline Analysis System (Appeaning Addo, 2008; Ford, 2011), remotely sensing data analysis and by creating models that can estimate coastal erosion (Corbella, 2012). The main purpose of this project is to identify and measured temporal changes, such as coastal erosion or accretion from 1930 to 2000 using different techniques on Environment Visualizing Images (ENVI) and Quantum geographic information system (QGIS).

MATERIAL AND METHODS

Study Area

Playa Jayuya is located on the eastern coast of Puerto Rico in the municipality of Fajardo and is a natural reserve under the administration of the Puerto Rico Conservation Trust. The study area is located in the northeast igneous province and is mostly composed of beach, swamp deposits and Hato Puerco formation (fig 1).

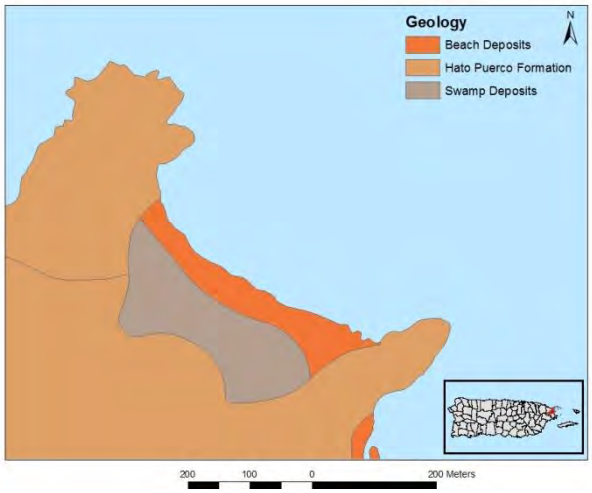

Figure1. Map of the geology of Playa Jayuya (Fajardo, Puerto Rico)

Image Processing

Shoreline changes were analyzed using a combination of aerial photography and satellite imagery. Aerial photos from 1930, 1950 and 1987 were used in this study. Satellite image from 2000 were acquired from the EarthExplorer website. (Table 1)

Aerial photography was georeferenced with QGIS using control points extracted from the satellite image. At least five control points were used for the procedure. A subset of aerial photography and image was performed using the resize tool from ENVI. Images were geometric and radiometric corrected. The Landsat ETM+ image was sharpened from 30meters to 15meters for the final analysis. Techniques from ENVI and QGIS were selected to identify shoreline change to see which had the most accurate and precise results.

Table1. Characteristics of aerial photography and satellite image used for the study

Date	Image type
2000	Landsat 7 ETM+
2/25/1987	Color aerial
11/25/1950	B/W aerial
1/16/1931	B/W aerial

Shoreline change: Neural Network classification

Neural network is a supervised classification from ENVI. To determine shoreline change the ROI tool was used to

create two different classes, land and sea. Neural Net was used for 1930 and 1987 aerial photography and 2000 satellite image. For each of the images 10 training iteration was selected. To determine rate of erosion or deposition for each of the images with the Region of Interest (ROI) tool a polygon was built to determine the area in square meters.

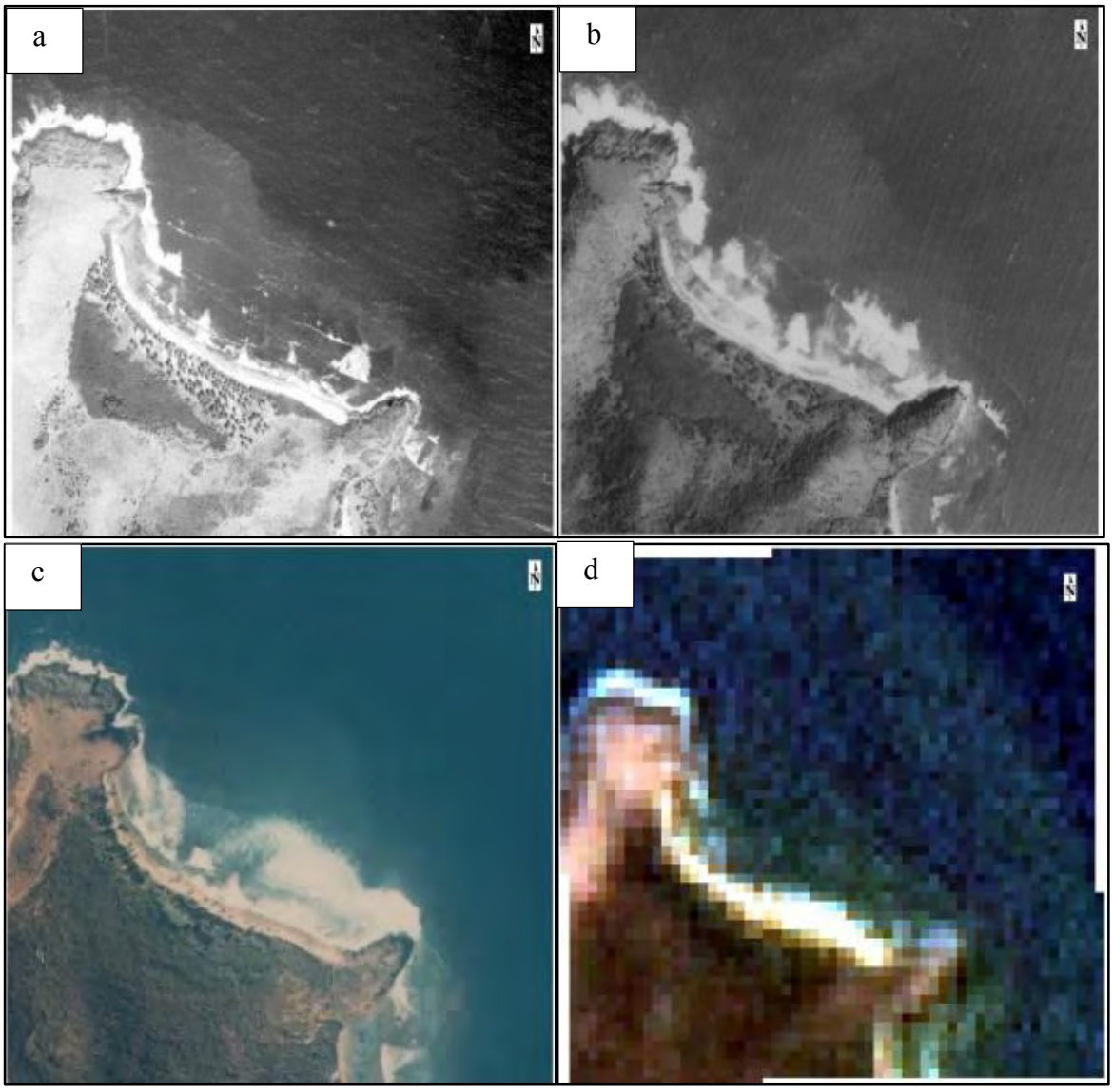

Figure 2. Subset of Playa Jayuya (a)1930 (b)1950 (c)1987 (d)2000-Satellite image

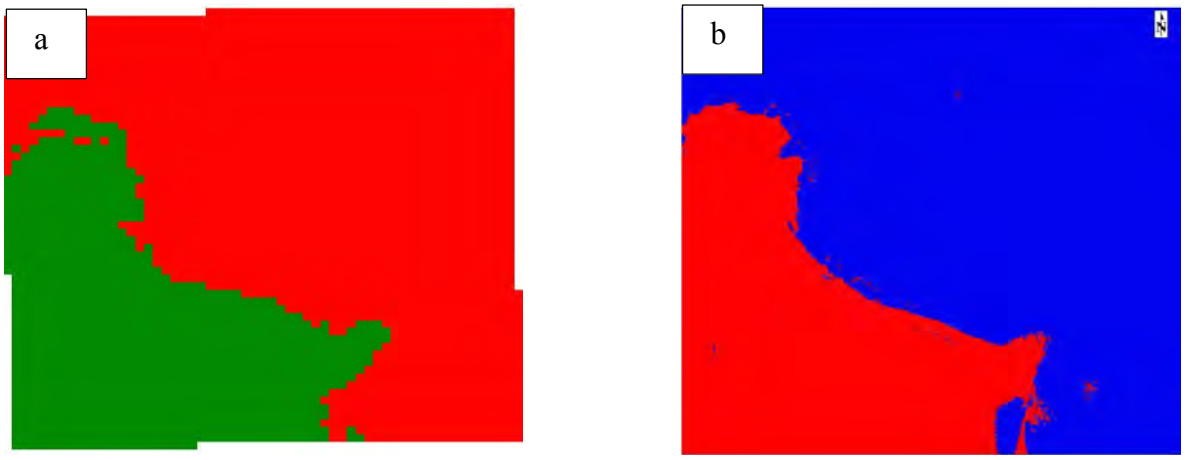

Figure 3. (a) 2000 Landsat ETM+ (red:sea; green:land) (b)1987 aerial color photography (blue:sea; red:land)

Shoreline change: Edge Extraction

The Edge extraction is a tool from the open source QGIS that is based on detecting edges in the image. It has different types of edge extraction; in this analysis was used edge extraction-gradient. Shoreline change was measured for a particular area in the subset using the vegetation line to water lines as proxy for changes detection.

RESULT

The Neural Network classification was performed only for three images in order to see the differences. The 1930 aerial photography is black and white and classification only work with multispectral images. In the case of the 1987 color photography and the 2000 satellite image has better results because they have more than one band. Figure 3a show the results of the satellite image (15 meters) after the classification and figure 3b showed 1987 aerial photography with two classes (land and sea). Figure 4 show the difference between the areas (m^2) from 1930 to 2000. Deposition occurred between the years of 1930 to 1950, while from 1950 to 2000 show high rate of erosion (table 2). High values from 1987 to 2000 may be because of the difference in spectral and spatial resolution of the satellite image.

The edge extraction technique showed reliable results for 1930, 1950 and 1987 aerial photography (figure 5). Edge vegetation and water line was identified using the original photography as guideline. For the 2000 image the results are more difficult to analyze due to low quality and resolution. Based on this information changes in the coastline were identified as rate of deposition from 1930 to 1950 of 0.15 meters, while from 1950 to 1987 the measure was -0.46 showing erosion for this section. From 1987 to 2000 higher rate of erosion were identify, in this case the analysis was made between a satellite image of 2000 and the 1987 aerial photography.

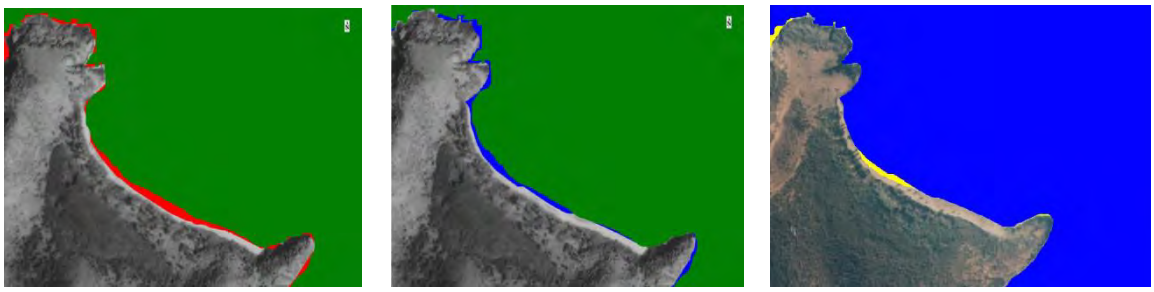

Figure 4. ROI data from 1930(red), 1950(green), 1987(blue) and 2000(yellow)

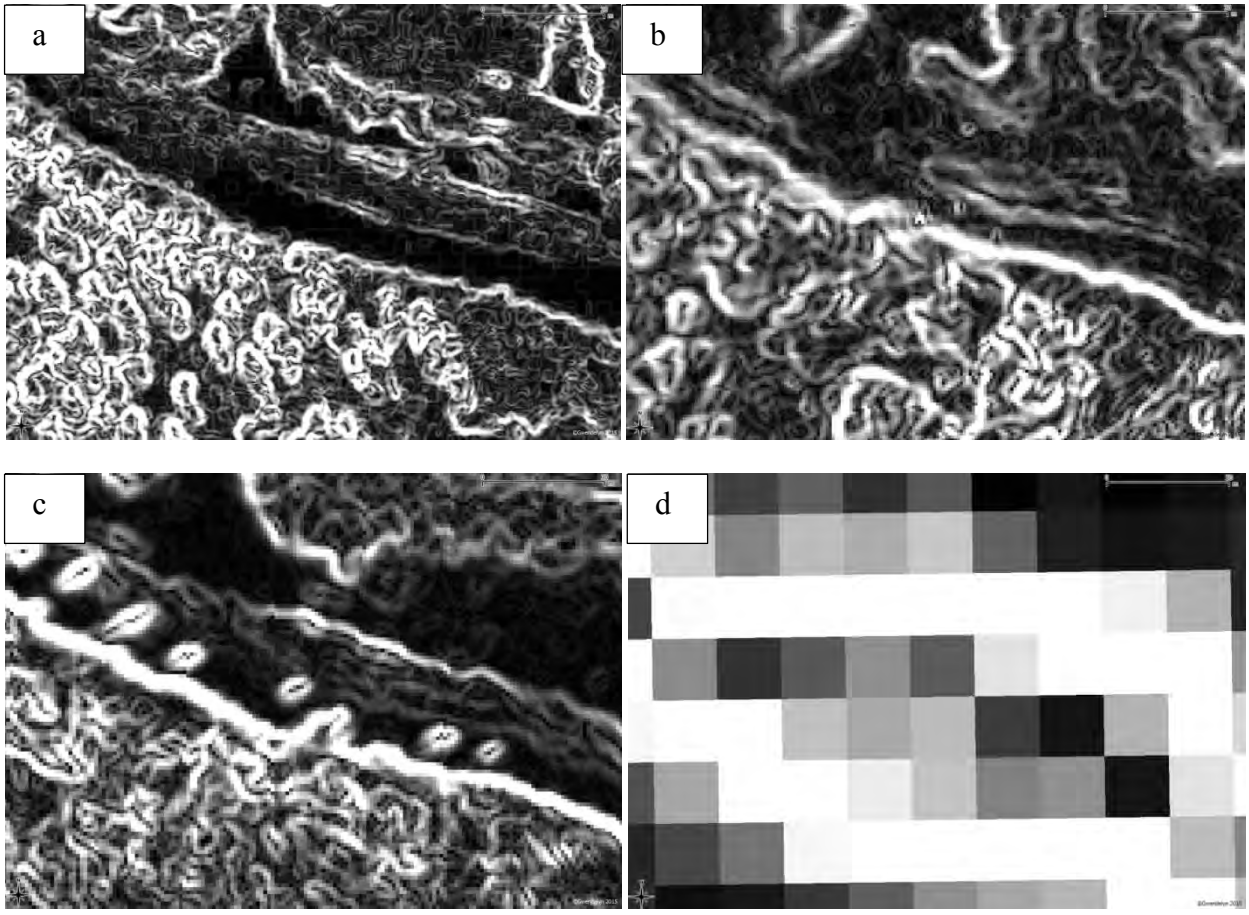

Figure 5. Edge Extraction (gradient) of aerial photography from (a) 1930 (b) 1950 (c)1987 and satellite image of (d) 2000 Landsat ETM+

Figure 6. Photo of Playa Jayuya 2015 showing an estimation of were the sea will in ~15 years.

Figure 7. Vegetation edge (archeological material) of Playa Jayuya

DISCUSSION

Even thou Neural Net classification is the most accurate method for differentiation in ENVI, in this case is more challenging because the data used for the analysis is a combination of aerial photography and satellite imagery. Low resolution of the satellite image is a limitation when creating the different classes; it is very difficult to identify the exact position of the shoreline. In addition this classification works with multispectral images and but is not going to work with black and white aerial photography.

The edge extraction shows more accurate results for shoreline change analysis such as the ROI data from ENVI that was used in order to compare different method to determine changes in Playa Jayuya. Both results (table 2) show deposition during the years of 1930 and 1950, while 1950 to 1987 rate of erosion increased. The fact that one of the objectives was to compare two different techniques by using a combination of aerial photography and satellite image could lead us to make unreliable estimation of the changes in playa Jayuya. Based on the data obtained from the analysis if erosion continue increasing at the same rate, the shoreline in approximately ~15 years will reach the vegetation edge, consequently the archeological area will be exposed(Figure6 and 7).

Table 2. Shoreline change from 1920 to 2000 data from Region of Interest (m^2) and Edge Extraction (m)

Year	Erosion Rate(m^2)	Erosion Rate(m)	
1987-2000	-9225.15	-1.142	Erosion
1950-1987	-107.73	-0.46	Erosion
1930-1950	233.27	0.15	Deposition

CONCLUSION

In general, both techniques can be used for shoreline change analysis but for Neural Net satellite image with higher resolution are required to identify changes. Edge Extraction (gradient) tool from QGIS is a technique that detect changes in the image and is also a technique that help identify changes throughout time.

The main objectives for this project were to explore new remote sensing

techniques to study, evaluate, and monitor shoreline change as well as determine erosion or accretion in Playa Jayuya. In this study the data obtain shows that erosion has increase since the 1950. If the rate of erosion continues to increase eventually the archeological material will be lost. In order to have more accuracy more years are need to see if there is a pattern and increase the accuracy of estimations of erosion rates.

RECOMMENDATIONS

Satellite image with higher resolution are required in order to run any supervised or unsupervised classification and in order to have better results. Exploring other tools for shoreline change analysis is recommended before any procedure.

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