Using Aerial Photographs to Compare Coastal Erosion in El Maní at Mayagüez, Puerto Rico, between 1930, 1999 and 2010

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Abstract

This research uses applications of remote sensing as a tool to compare the evolution of the shoreline in El Maní at Mayagüez Puerto Rico. Studies about coastal erosion are very important in Puerto Rico since it is happening drastically and it is affecting not only the biota that lives in the oceans, but structures that are close to the beach as well as human lifestyle. Coastal erosion can be caused by natural and anthropogenic activity. Other factors such as deposition, can also been contributing to erosional features. Using ENVI software it was possible to edit three aerial photographs from 1930, 1999 and 2010 from El Maní, Mayagüez, Puerto Rico area. A coast line was made to demonstrate a comparison of approximately 80 years in terms of erosion. As a result for this comparison, the changes were mostly related to deposition. Also, a Supervised Classification (Maximum Likelihood) was made in order to compare changes in vegetation, structures, and population. The results for this classification were not expected since no dramatically changes were obtained. The results of this study were analyzed based on qualitative methods.

Keywords: Coastal Erosion, Deposition, ENVI, Aerial Photographs, Mayagüez

Introduction

The National Research Council of United States (1990) defines coastal erosion as the process by which coastlines and beaches are worn out. This process is caused by wave action, wave currents and other natural and anthropogenic factors (McNab et. al, 2011). Puerto Rico is located in the Caribbean and most of the infrastructure is located near the coast. Coastal erosion changes will affect not only the geomorphology of the Island but also the infrastructure and human lifestyle, socially and economically.

Storm surge can be one of the major hazards affecting the coast. Also, in 1998, Hurricane Georges caused extremely high storm surge in the north coast of Puerto Rico (Turnipseed et. al, 1998). Aerial photographs will not evidence dramatic changes but they can be helpful for shoreline changes due to episodic events such as storms (Barreto and Morelock, 2000). Depositional events can also be attributing to coastal erosion. After a stormy event, marine and terrigenous events can mix due to turbidity and can be carried to the coastline (Barreto and Morelock, 2000).

Motivated by the drastic changes seen in the coastal areas of Puerto Rico, this research is focused on coastal erosion. The purpose of this project is to make a comparison between aerial photographs from 1930, 1999 and 2010. By analyzing coastal features we will be able to determine how coastal erosion has affected El Maní coast from 1930 to 2010. Using aerial photographs as a remote sensing technique was helpful for conclusions on what phenomena causes or contributes to these changes. The images produced will be analyzed and processed using ENVI software.

Methods

In order to compare coastal erosion in El Maní at Mayagüez, Puerto Rico (Image 1) between 1930, 1999 and 2010, the software ENVI (Environment for Visualizing Images)

was employed to identify coastal changes in the desired time interval.

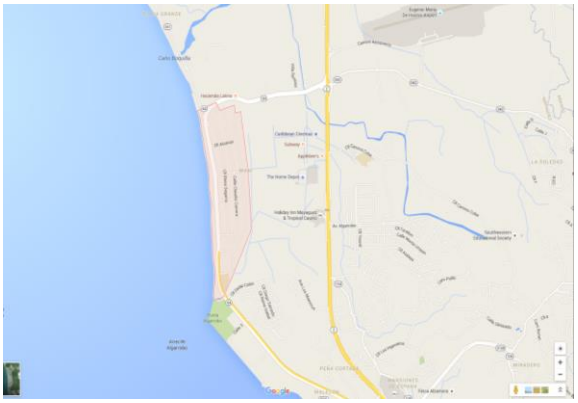

Image 1: Google Earth image showing the selected study area, El Maní at Mayagüez Puerto Rico identified in the red polygon.

Data

For this research, aerial photographs were obtained from different databases depending on the chosen study year. Photographs from 1930 and 1999 were freely available at the Porto Rico 1930 Aerial Image Database website (http://pr1930.revistatp.com/) and the CCMA: Center for Coastal Monitoring & Assessment website (http://www8.nos.noaa.gov/biogeo_public/aerial/search.aspx) respectively. Dimaris Colón, current graduate student at the University of Puerto Rico at Mayagüez, provided the required aerial photograph from 2010. The selected aerial photograph from the starting point, 1930 was available in black and white and characterized by a very low resolution due to the year the photograph was taken (Image 2) while images from 1999 and 2010 were in true color and with a clearly shown, better resolution (Image 3 and Image 4).

Image 2: 1930 black and white aerial photo (raw) from El Maní at Mayagüez, Puerto Rico.

Image 3: 1999 true color aerial photo (raw) from el Maní at Mayagüez, Puerto Rico.

Image 4: 2010 true color aerial photo (raw) from el Maní at Mayagüez, Puerto Rico.

ENVI processing

The aerial photographs were individually opened at the ENVI software. The 2010 photograph was georeferenced but the 1930 and 1999 photographs were not. To avoid potential errors in the results of this research, the first step was to georeference both, the 1930 and the 1930 photographs, using as base the 2010 photograph. For this step, the "Ground Control Point" tool which can be found under the Registration to Image tool in the ENVI. A total of 8 "Ground Control Points" were selected for both photographs.

Once the three photographs were georeferenced the next step was to select the region of interest. The "Spatial Subset" tool was employed (in all the photographs) to achieve this step.

To determine coastline changes it was necessary to trace the coastline in each aerial photograph. The selected tool to perform

this step was “Region of Interest (ROI)”. The coastline was trace using the polyline option and then saved as an individual file to create a coastline mosaic in the most recent aerial photograph (2010). With each ROI saved individually it was possible to compare the coastlines in the different years. Since the 1930 photograph was only available in black and white the coastline was traced based in the differences between the colors (black and white), for the 1999 and 2010 photograph it was possible to trace the coastline based in observation (using the zoom tool).

Supervised Classification was the tool that allowed the traced coastlines to be validated. Due to the lack of resolution of the 1930 photograph it was not possible to perform the classification in this image. Maximum Likelihood classification was run in the 1999 and 2010 photographs, using a ROI file including 3 classes (city, vegetation and ocean).

Results

Images 5 – 7 shows aerial photographs from El Maní in Mayagüez, Puerto Rico after being processed in the ENVI software to identify coastline changes. As previously discussed, due to the low resolution of the 1930 photograph, the coastline was traced based on the black and white differences. Image 5 shows a spatial subset of the raw 1930 aerial photograph with its coastline trace in light red. For the 1999 and the 2010 it was easier to trace the coastline image 6 shows a spatial subset of the 1999 aerial photograph with its coastline traced in blue while image 6 shows a spatial subset of the 2010 aerial photograph with its coastline traced in purple.

Image 5: 1930 aerial photo from El Maní. The coastline is traced in red.

Image 6: 1999 aerial photo from El Maní. The coastline is traced in blue.

Image 7: 2010 aerial photo from El Maní. The coastline is traced in purple.

To better visualize coastline changes, the ROI files containing the 3 traced lines where merge to create coastline a mosaic. Image 8 shows the coastline for the 3 selected years (1930, 1999 and 2010). With this mosaic we observed that this coast shows was a depositional patter. This could be due to it nearness of 2 river mouths, Añasco y Yagüez.

Image 8: Mosaic of coastlines from 1930, 1999 and 2010.

Supervised classification, specifically maximum likelihood, with 3 classes was run in the 1999 and 2010 photographs. The specific classes were city, vegetation and ocean. Image 9 represents a depositional scenario for El Maní coastal area. The green color is the present beach (2010), blue color represents 1999 shoreline, and yellow represents 1930 shoreline. Image 10 corresponds to the supervised classification for 1999 and Image 11 corresponds to supervised classification for 2010. Both classifications were very accurate specifically classifying changes in infrastructure (city class). It was expected to see a reasonable change in infrastructure, but comparing both images, this cannot be hypothesized. It has to be studied from upper regions (higher elevations), different from the coast area, in order to see if changes that could be contributing to the depositional features, can be identified.

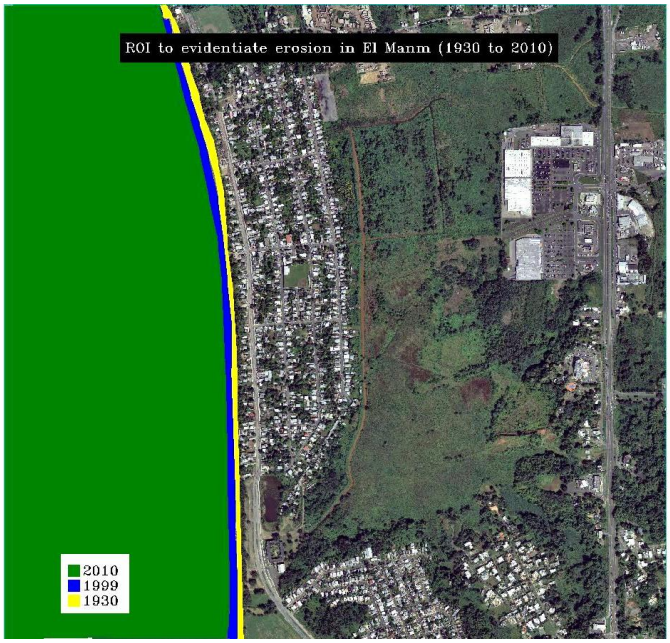

Image 9: ROI file showing deposition in El Maní, from 1930 to 2010.

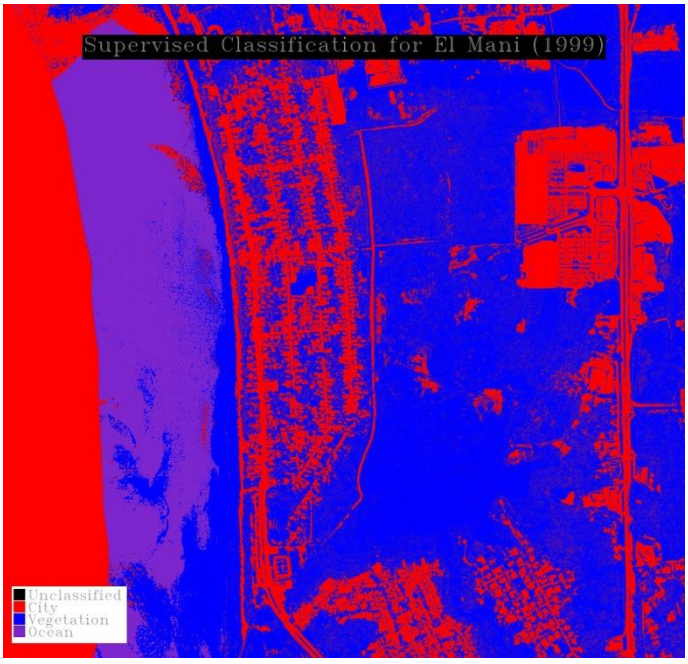

Image 10: Supervised classification, Maximum Likelihood for El Maní 1999 aerial photograph.

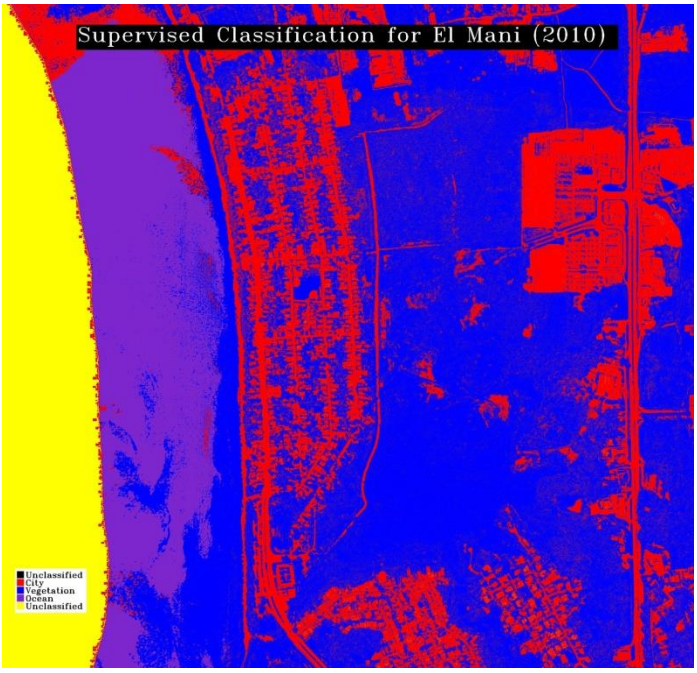

Image 11: Supervised classification, Maximum Likelihood for El Maní 2000 aerial photograph.

Conclusion

Employing qualitative methods and the ENVI software, it was possible to make a comparison between 1930, 1999 and 2010 aerial photographs, tracing a shoreline at the coast of El Maní in the chosen time interval. There were changes in shoreline in the coast of El Maní during the years 1930, 1999 and 2010. After analyzing the results of this research, it was notorious that deposition events are dominant in the selected coast (El Maní). To determine the reasons of the deposition in this coast it is necessary to analyze the environment and structures of the beach making emphasis on place and scale. The accumulation of sediments along a coast is common when the coast is near a river mouth, which is the case of El Maní. A Supervised Classification (Maximum Likelihood) was made for aerial photographs from 1999 and 2010, where the main purpose was to compare city and vegetation in a decadal time. There were no

significant changes in infrastructure. However, constructions very close to closed were evident and anthropogenic actions were not discarded as a contributor factor of changes in the coast of El Maní.

Recommendations

Since there are many on-going coastal studies for the Puerto Rico region, we recommend to compare this study to others performed near Mayagüez, Puerto Rico. This could validate the results of this research. Since this project was qualitative in nature, for further analysis of the data acquired for this project it suggested to realize a prediction of the future coastline for El Maní based on quantitative methods. Analysis of the currents, the coral reefs and the geomorphology the study area will be helpful to understand the deposition patterns of this coast.

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