

Coverage of Mangrove Ecosystem along Three Coastal Zones of Puerto Rico using IKONOS Sensor

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Abstract.-Puerto Rican mangroves have great ecological and environmental importance since they serve as natural barriers for coastal erosion in atmospheric events. Mangroves are excellent evapotranspirants, supplying humidity to the atmosphere. Unfortunately, these ecosystems have been decreasing over the past few years coinciding to the increase in population. Previous research has led to conclusions that mangroves are indeed being affected by anthropogenic activity. The purpose of this study is to determine and compare the mangrove coverage along three coastal zones in Puerto Rico: La Parguera, Piñones and Puerto Mosquitos and see if these values correlate to any urban development. IKONOS sensor images from 2001-2003 were processed to obtain the Normalized Difference Vegetation Index (NDVI). Also a Supervised Classification was done using Maximum Likelihood and Minimum Distance routines to show four regions of interest: ocean, agriculture, infrastructure and mangrove. Statistical analysis demonstrated that Vieques had the greatest mangrove coverage with a 50.8% in comparison to Piñones and Parguera with a 23.4% and 14%, respectively. NDVI statistics were 0.74 for Parguera, 0.99 for Vieques and 0.96 for Piñones meaning healthy mangrove population. The designated land use for infrastructure for this study did not show a huge impact on mangroves coverage compared to previous research since these areas were located in regions either protected or in coastal areas with low urban development.

Keywords.-*La Parguera, NDVI, Piñones, Supervised Classification, Vieques*

INTRODUCTION

Mangrove ecosystems are a community of tropical trees found in coastal intertidal zones. These communities have the ability to survive stress conditions such as flooding and salinity caused by coastal environments (Hoff et al., 2002). Environmentally, these forests are of great importance since they serve as stabilizers and as natural barriers against coastal erosion from atmospheric events such as storms; they also provide protection to other marine ecosystems (e.g. coral reefs) from receiving sediments coming from inland (Lovelock et al., 2005). However, worldwide, mangroves have been decreasing by a 35% since 1980s (Martinuzzi et al., 2008). This decline is due to anthropogenic impacts, especially those related to urban development. It has been proven that there is a strict relationship between human activities and today's

landscape. As population grows, changes in the environment are going to occur affecting its surroundings from its economy to land use to coastal development. This panorama is no exception for Puerto Rico.

Puerto Rico's population has dramatically changed over the past 200 years: its population has increased from 50 people per square kilometer up to 400 people per square kilometer (Martinuzzi et al., 2009). During the 70's, the Department of Public Works noticed that the communities of mangroves were decreasing (Heathole, 1985). This decline has been occurring long before the 1940s when Puerto Rico's economy was based on agriculture. Figure 1 shows that mangrove forests started declining from 12 thousand hectares in 1800 to 6 thousand hectares for 1940s approximately due to agriculture

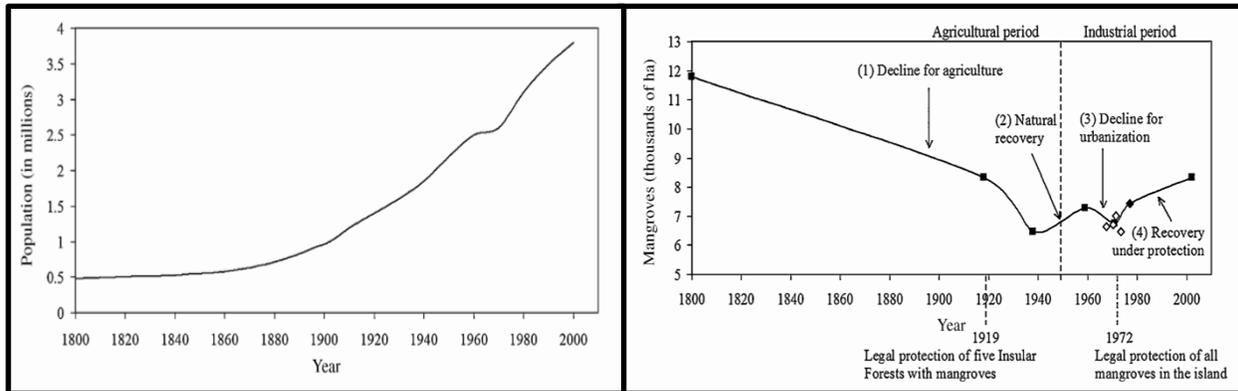


Fig. 1. Correlation between Puerto Rico's population with the decline in mangrove ecosystems. A. Represents an increasing population for Puerto Rico. B. Represents the decrease in mangrove through time.

caused deforestation and as a consequence, the pesticide used for the maintenance of crops reached coasts causing runoff contaminating the mangroves. Once industrialization began, people left the crops and moved to what is now known as the city for a better job opportunity which represented a better quality of life. A natural recovery is then seen in 1950s but then again, mangroves experienced another decrease around 1970: mangroves located at the city were been affected by the rapid urban expansion (Martinuzzi et al., 2009), which led to the dredging and filling of wetland and mangrove habitats. These communities are still seen in the metropolitan area and are known as Canteras, Barrio Obrero, among others since they are the generations of those families who left the agricultural fields looking for progress.

Using IKONOS Sensor, remote sensing for detecting vegetation was along La Parguera (Lajas), Piñones (Loiza) and Puerto Mosquito (Vieques) with the purpose of determining the

Normalized Differenced Vegetation Index, also known as NDVI, to obtain the value of mangrove coverage and relate them to land use.

METHODOLOGY

Study Area

Due to the availability of IKONOS Sensor images, three sites (Fig. 1) were chosen along the coasts of Puerto Rico: north, south and east. This is done in order to record the variability in mangrove coverage between these areas.

Preprocessing Images

Since the IKONOS bands were provided individually for each site, a *Layer Stacking* was done first, followed by a mosaic, in order to produce one image per site.

Processing IKONOS images

Once the images are preprocessed, a spatial subset was done to each image to depict the area of research.

In order to make a Supervised Classification, four Regions of Interest, (ROIs) were chosen to designate land use around the mangrove habitats. These regions consisted of: mangrove itself, ocean, agriculture and infrastructure. For each site, the images were processed to obtain both Maximum Likelihood and Minimum Distance and see which one highlighted these ROIs better. The Normalized Difference Vegetation Index was then calculated to produce an image for each site showing where the mangroves are healthier, (value near or of 1) meaning greener and abundant.

RESULTS and DISCUSSIONS

Puerto Mosquito Site at Vieques showed to have a greater coverage of mangrove with a 50.8% in comparison to Piñones and Parguera with a 23.4% and 14%, respectively (Graph 1-3). This might be attributed to the fact that this particular area for Vieques has low coastal development whereas Piñones, even though it is located at a well-developed area, (metropolitan area), it is protected by Federal Agencies. As for Parguera, it resulted to have the lowest coverage of mangrove because in comparison to the other two sites, this one was the most densely populated. For the NDVI values (FIG. 3.), an overall of healthy coverage, meaning greener and abundant (values near or of 1), was calculated. The values ranged from 0.99 for Piñones, 0.96 for Puerto Mosquitos and 0.74 for Parguera. For the Minimum Distance and the Maximum Likelihood (Fig. 2) we obtained that bright values represent infrastructure, but as it is

showed, sand and coral reefs are highlighted as infrastructure.

The results from this research contradicted most of the findings in previous research. Land use did not have an effect nor impacted negatively the mangrove ecosystem. In other words, an urban development as a consequence of population increase did not represent any hazards to the health or coverage of mangroves. During past years, when agriculture was the base of the economy, mangrove forests decreased because of the high rate of erosion and runoff sedimentation this practice provoked. As the industrial era began, these crop fields became abandoned, allowing the forests to recover. But the damage was already done; mangrove ecosystems could never reach its maximum peak. As years passed by, Puerto Ricans have developed some conscience concerning our landscape: “population growth is compatible with forest recovery” which according to Martinuzzi et al., 2009, it is related to the postulate that describes the history of Puerto Rico’s landscape (Martinuzzi et al., 2009). It is all related to the socio-economic status of the island, where conservation of our resources is the key to a better progress.



FIG. 1. IKONOS images. From left to right: La Parguera, Puerto Mosquito, Vieques. Bottom image: Piñones.

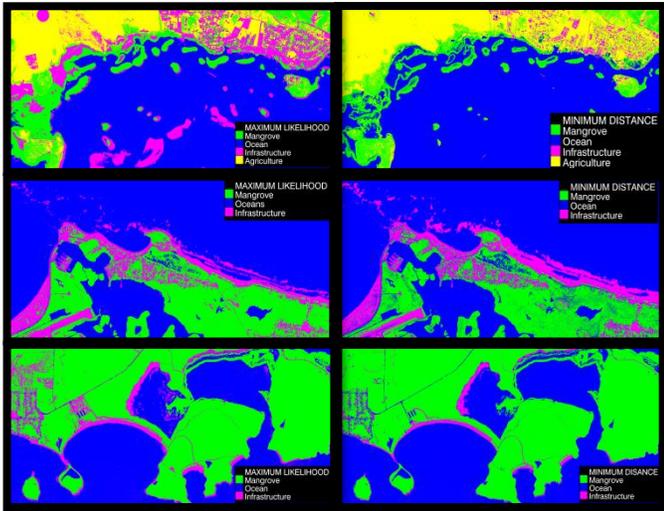
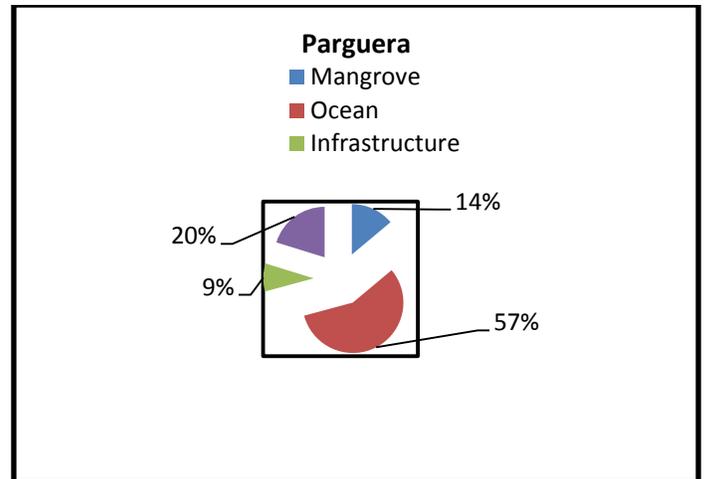


FIG. 2. Maximum Likelihood and Minimum Distance for three coastal zones. From top to bottom: Parguera, Piñones and Vieques.



Graph 1. Land use percentages for La Parguera Site.

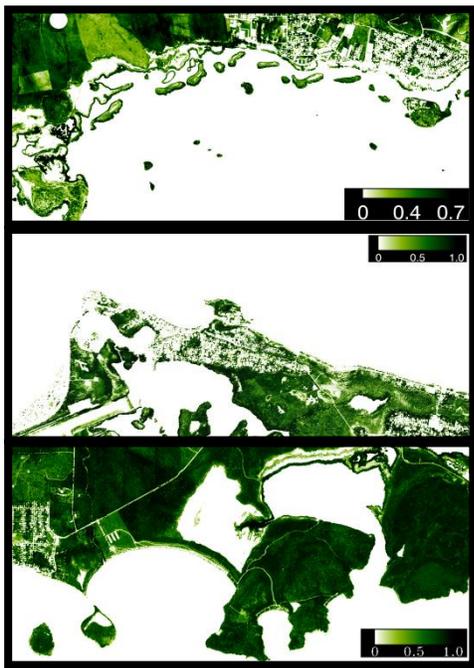
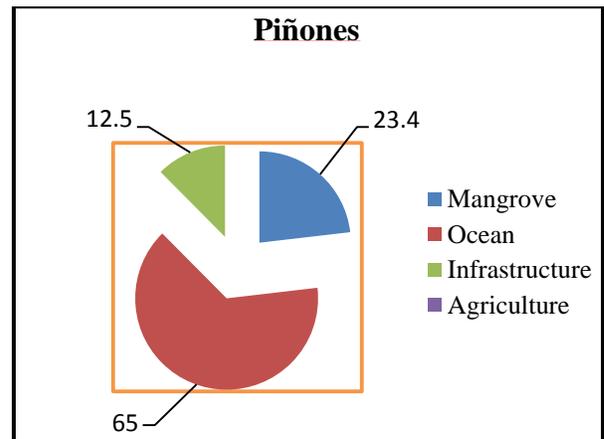
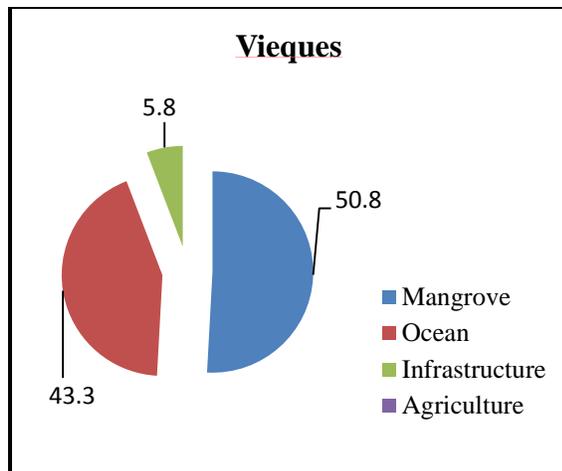


FIG. 3. NDVI values. From top to bottom: La Parguera, Piñones and Puerto Mosquito, Vieques



Graph 2. Land use percentages for Piñones site.



Graph 3. Land use for Puerto Mosquito at Vieques.

CONCLUSIONS

The designated land use for infrastructure for this study did not show to influence mangroves coverage since they were located in regions either protected or in coastal areas with low development. This is reasonable if the rate of mangrove forest growth is faster than the population growth. Once the population growth rate is higher than the growth rate of mangroves, these communities will be affected just like 1800s and 1940s, where agriculture and then industrialization took over Puerto Rico's economy. However, it is important to highlight that previous research has led to conclusions that mangroves are indeed being affected by infrastructure and other anthropogenic factors. According to the Inventory of Mangroves in Puerto Rico, Piñones is being affected constantly by dredging and filling and urban development, la Parguera by activities that involves boating and Vieques, is by a clandestine landfill.

RECOMMENDATIONS

For this study, errors in processing images and in the interpretation of the data obtained influenced the results. For this reason the following recommendations are mentioned for future acknowledgment:

- Process more images in order to develop a sequence in time and be able to see changes in mangrove coverage through time. (Temporal Resolution)
- Choose more areas of same dimension for each region of interest
- Use aerial photography as a base for determining usage of land throughout time
- Quantification of area in km²
- Validation of remote sensing data with field data
- Standardize the ocean and coast parameters in order to minimize the errors obtained when calculating the statistics.

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