<u>Vegetation Studies in Puerto Rico Using Remote Sensing Techniques</u>

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Abstract

The purpose of this work is to assess the vegetation density changes in Puerto Rico over the last 12 years (2003 – 2015) using satellite imagery. The images chosen were from the sensors ETM+ and OLI, respectively. Processes of NDVI and supervised classification were run using ENVI 5.2 software. The total coverage area was calculated using the spatial resolution of each sensor and the number of pixels classified as vegetation. After analyzing both images, it was concluded that the vegetation in Puerto Rico had increased in the stipulated time period by 2,038,020 m^2.

Keywords: forest, recovery, vegetation

Introduction

In this work the main focus is to explore vegetation changes in Puerto Rico over the last twelve years. The inspiration for this project was the work done by G. Arturo Sánchez-Azofeifa, Robert C. Harriss and David L. Skole in 2001 which assessed the deforestation problem in Costa Rica for five years (1986 – 1991). The authors used imagery from Landsat Thematic Mapper and developed a forest cover map using GIS software. The estimated deforestation rate for Costa Rica in the years 1986 and 1991 was 450 km^2 per year (Sánchez et. al. 2001).

Originally, this work was going to assess the deforestation rate in Puerto Rico, rather than just doing a general vegetation study. After doing some more research, and with the feedback of peers, a study from H. Ricardo Grau, T. Mitchell Aide, Jess K. Zimmerman, John R. Thomlinson, Eileen Helmer and Xioming Zou done in 2003 stated that the deforestation trend in Puerto Rico was different from other tropical areas. Instead of deforestation, Puerto Rico had actually experienced forest recovery since 1940 (Grau et. al. 2003). The reason for this forest recovery was the fact that after the late 1930's the industrialization of Puerto Rico displaced the socioeconomic status of the island (Grau et. al. 2003). Lands in Puerto Rico before 1940 were being used as agriculture lands, therefore the deforestation rate was considerably high (Grau et. al. 2003). Once industrialization settled in, there was not as many people working with agriculture, so the island experienced forest recovery (Grau et. al. 2003). The authors used images from Landsat Thematic Mapper as well from the years 1991 and 1992 and developed a map considering parameters like population between 1940 and 1990 and geoclimatic zones (i.e. humid forests, dry forests, etc.) (Grau at. al. 2003). They estimated that about 42% of the island was covered in forests as of 2003 (Grau et. al. 2003). In light of this study that was found, the main focus of this work was changed.

Methodology

The main purpose for this entire project was to get familiarized with ENVI 5.2 software and be comfortable enough to develop an original study which could be aided by this program. Materials used in this work involve two satellite images: one from ETM+ (Landsat 7) and the other one from OLI (Landsat 8). The images are from 2003 and 2015 respectively. Both images were acquired via earthexplorer.usgs.gov database. The files were decompressed using the free software WinRAR. The bands were all separated so the “layer stacking” tool was used to put all bands in a single image. A spatial subset was selected in order to crop out as much water as possible. The NDVI (Normalized Difference Vegetation Index) was calculated using the following formula:

$$\text{NDVI} = \frac{\text{NIR}-\text{red}}{\text{NIR}+\text{red}}$$

Once the NDVI was calculated, a mask was needed to hide all unwanted values outside of the range 0 – 1. The mask was applied along with a color palette to differentiate the vegetation density.

Since there needed to be a way to quantify how much the vegetation had changed over the designated period of time, a supervised classification process was run using “minimum distance”. For the ETM+ image 5 classes were chosen as regions of interest (ROI): vegetation, ocean, city, clouds and roads. For the OLI image the same classes were chosen except for roads. Annotations for both NDVI and Minimum Distance images were added using the ENVI classic software.

Results and Discussion

In the following section the results for this work will be discussed while comparing and contrasting all four images.

As mentioned in previous sections, vegetation in Puerto Rico has experience a growth since the 1940's and with this study it was fairly clear that conclusion. Figures one and two represent the western, mid-western part of Puerto Rico with the NDVI calculated. From a purely visual standpoint, it can be seen that figure 2 has deeper green tones than figure 1. The color scale has been adjusted so that the higher the vegetation density, the deeper the color green of the NDVI. The change in green is more obvious in the north part of Puerto Rico, near Aguadilla. Overall the image from 2015 shows a higher amount of vegetation than the image from 2003, which supports the studies done previously by Grau et. al. in 2003. However, only comparing both NDVI images one cannot tell exactly how much the vegetation increased over the last 12 years, which is why a supervised classification process was run.

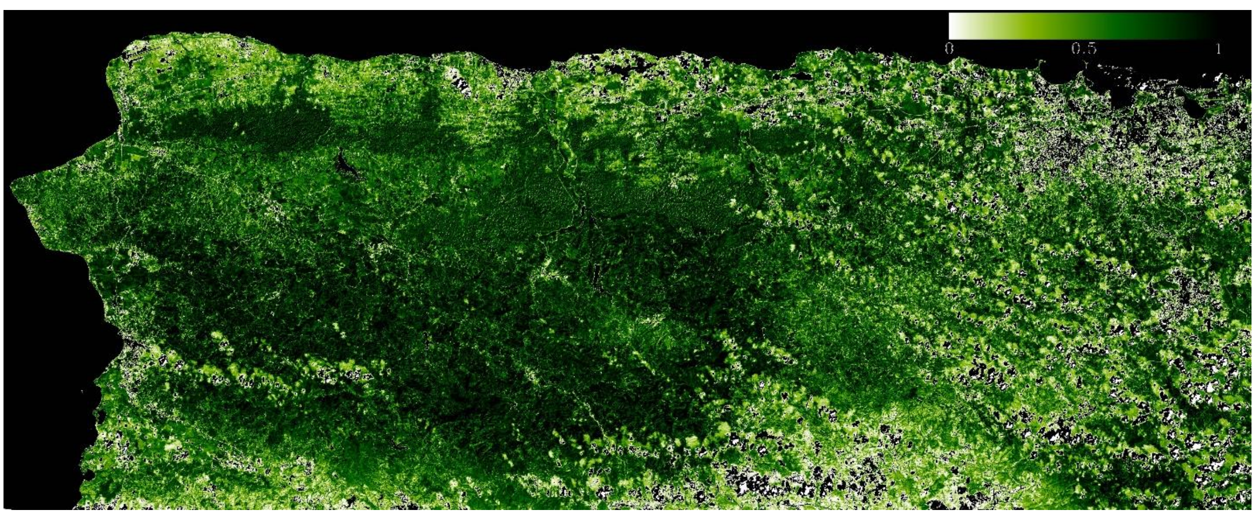


Figure 1: ETM+ NDVI

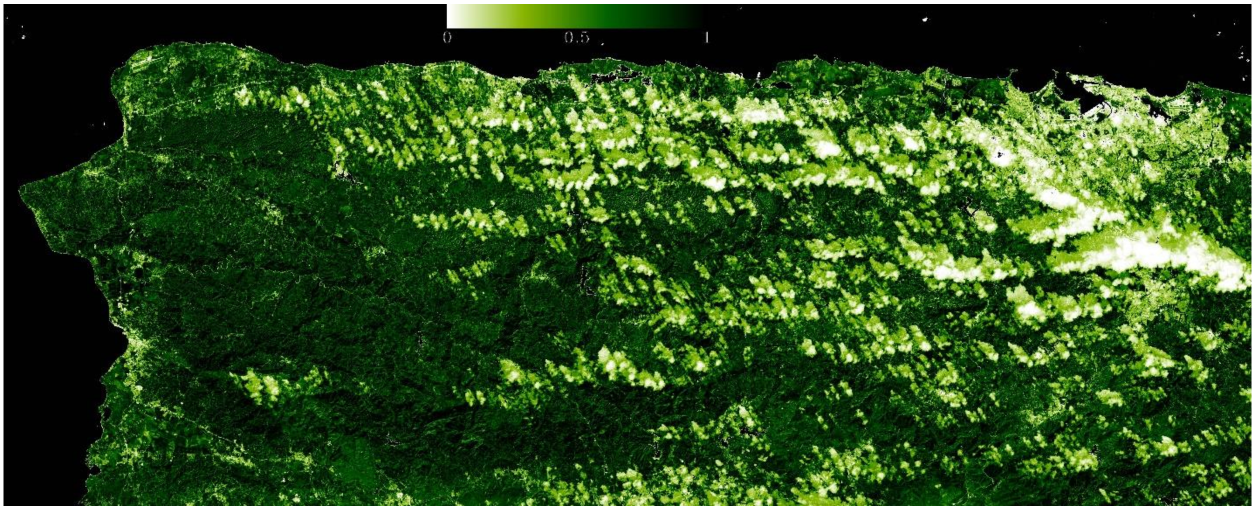


Figure 2: OLI NDVI

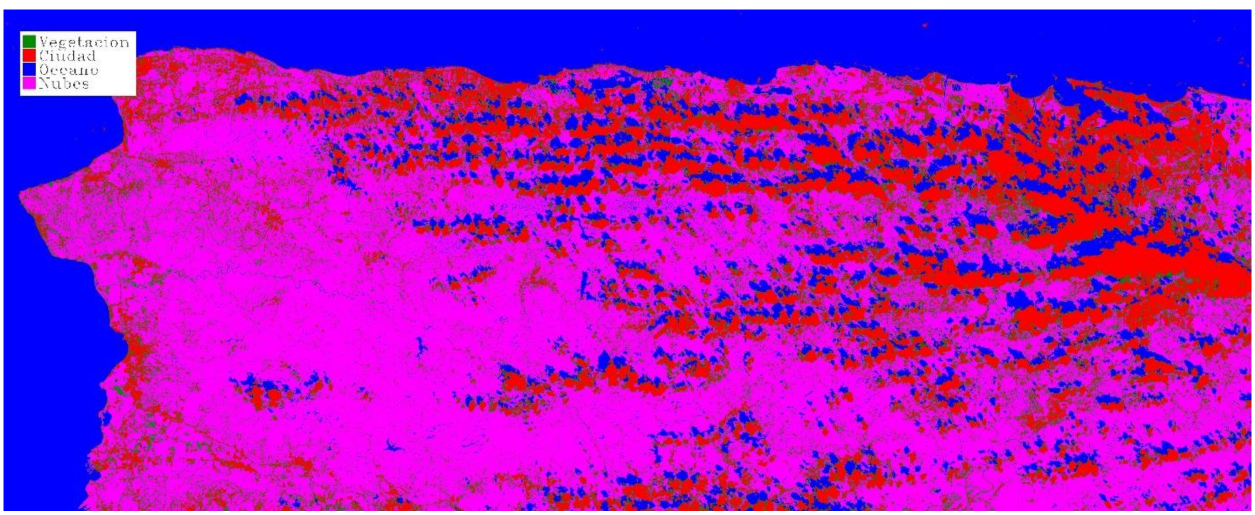


Figure 3: ETM+ Minimum Distance

Figures 3 and 4 represent the same spatial subset with the Minimum Distance classification process run. There were various issues when running the supervised classification. Originally, it was planned to run a Neural Network classification, but the outcome could not be used. Maximum Likelihood was also tested, but the results from Minimum Distance were the most effective. With the supervised classification, it gave a way to quantify how much the vegetation had increased in the last 12 years. For the ETM+ image five classes were chosen: vegetation, city, roads, clouds and ocean. The most obvious issue is that the program classified part of the vegetation as "road" (the yellow parts). Another issue was the shade of the clouds, which were classified as part of the "ocean" class. The process was run several times but it yielded the same result. The OLI image on the other hand, the vegetation class was supposed to be green but it classified the vegetation as clouds. And the clouds are classified as part of the city class. Even

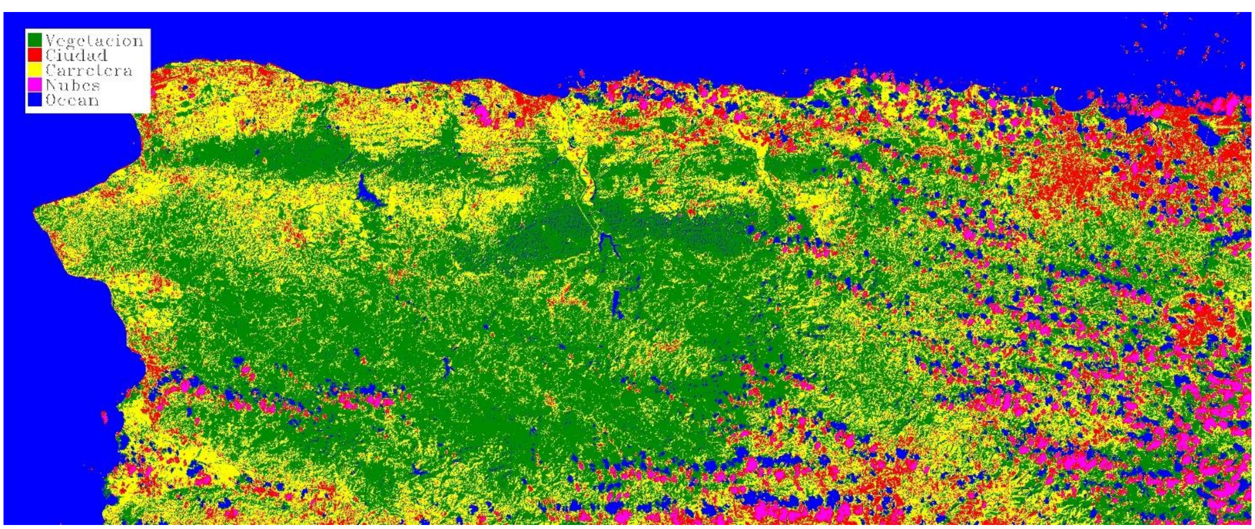


Figure 4: OLI Minimum Distance

though the classes did not exactly match, the image was used because it delimited the edge of the city with the vegetation really well.

Figures 5 and 6 represent the quantitative analysis that was used to determine the change in vegetation. The histograms show the pixel count of each of the classes. The area of vegetation increase was calculated by multiplying the pixel count times the spatial resolution of the sensors (30m x 30m for both ETM+ and OLI). For the ETM+ image from 2003 the vegetation cover area

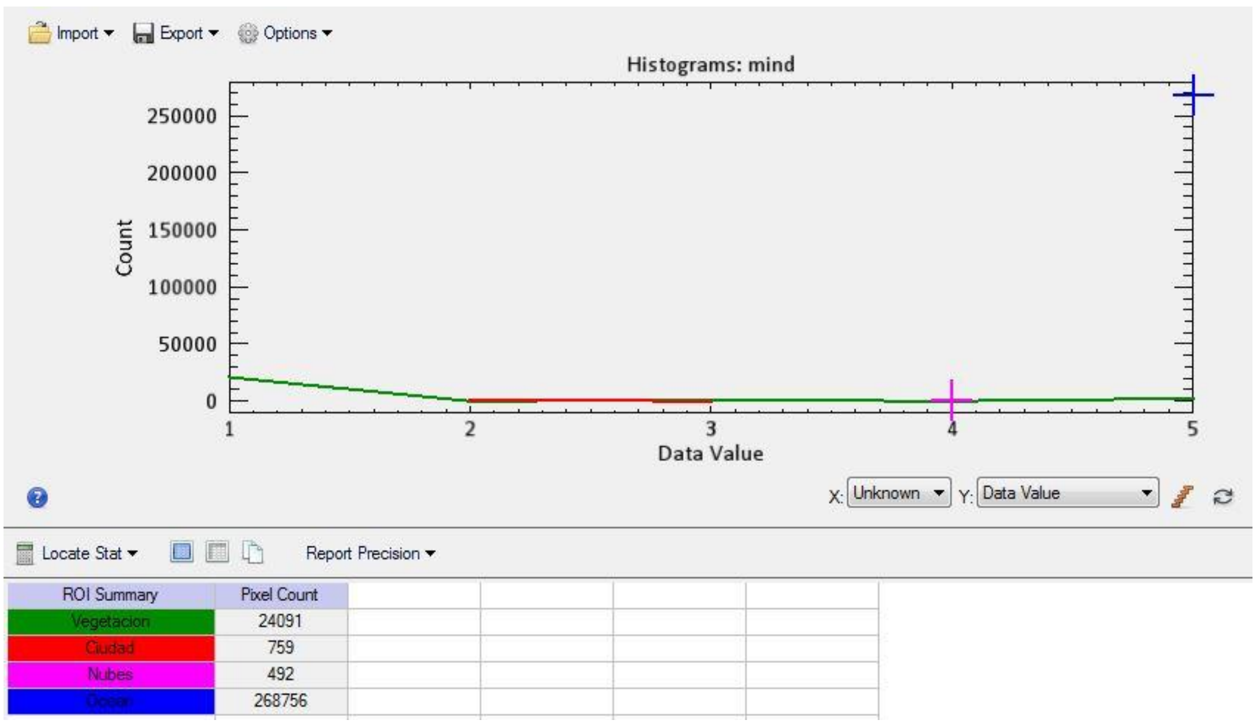
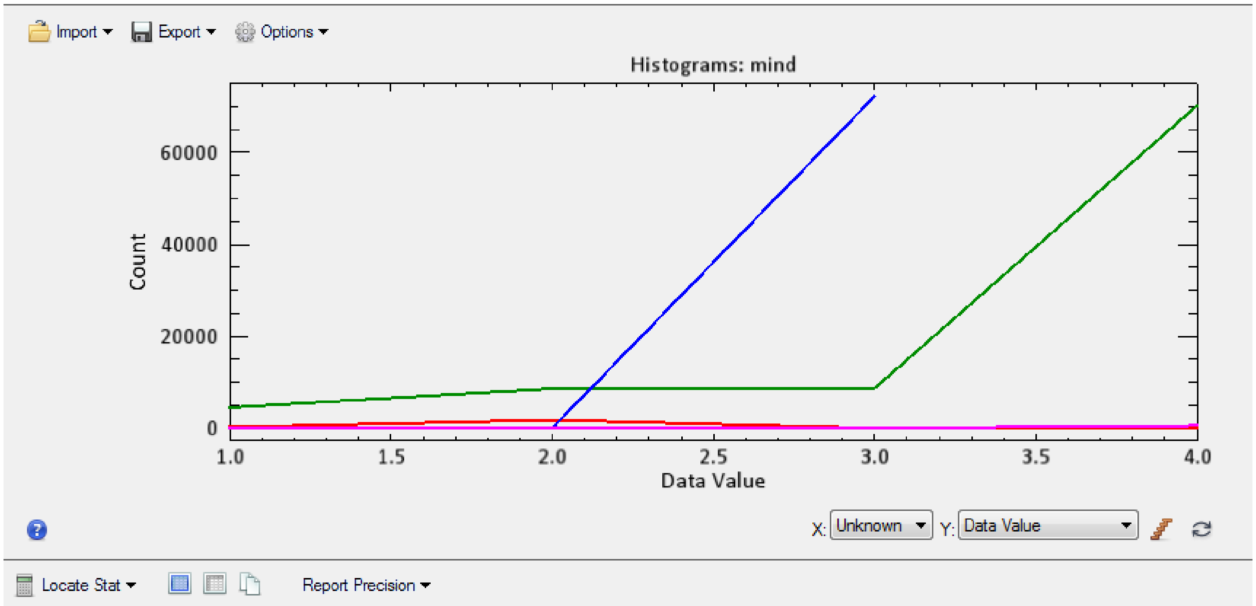


Figure 5: ETM+ Histogram

is 722,730 m^2. The OLI image from 2015 yielded a result of 2,760,750 m^2. The difference between these two results is 2,038,020 m^2, an average of 169,835 m^2 per year. The vegetation in



ROI Summary	Pixel Count
Vegetacion	92025
Ciudad	2018
Oceano	72251
Nubes	686

Figure 6: OLI Histogram

Puerto Rico recovered quickly because the climate is ideal. Heavy rains and fertile soils are excellent for vegetation growth.

Conclusions and Recommendations

The vegetation in Puerto Rico experienced a rapid growth after the 1940's and it has been steadily increasing in the last 12 years with an average of 169,750 m^2 per year. The methods used in this study are not entirely accurate, although they do coincide with previous studies, which is why it is always important to make field studies and corroborate the information obtained from remote sensing techniques. Remote sensing is an extremely useful tool which allows the scientific community to make studies at large scales and extract quantitative information from the images. Another recommendation would be to continue monitoring the rate of vegetation growth constantly, and compare if it follows the same trend as established here.

References

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