Vegetation Index of Puerto Rico during the La Niña 2021 and El Niño 2015 events in the Municipality of Guánica

Román Pérez, Carlos E.[1], Pabón Hernández, Mónica B.[2], Torres González, Yadiel[2]
Department of Geology, University of Puerto Rico at Mayagüez, Mayagüez, P.R.[1]
Department of Physics, University of Puerto Rico at Mayagüez, Mayagüez, P.R.[2]

Mentor: Dr. Fernando Gilbes Santaella
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I. Abstract

This study focuses on identifying the effects of the La Niña 2021 and El Niño 2015 in the vegetation of the Guánica region. Utilizing Level 2 images captured from Landsat 8 Operational Land Imager (OLI) of Guánica from 2013, 2015, and 2021 of the months of July, these images were analyzed utilizing ENVI 6.1 software to create Normalized Difference Vegetation Index (NDVI) images, and the 2015 and 2021 images were compared to the 2013 neutral phase to directly visualize the changes. Results showed that the ENSO region directly affects the vegetation of Guánica, as the 2015 Niño showed mean NDVI values of 0.404 in comparison to the 2013 Neutral phase which showed mean values of 0.554, which shows the reduction of the vegetation in the region. In the 2021 La Niña, mean NDVI values were of 0.451 while the 2013 Neutral phase had mean values of 0.554, which shows that La Niña does not increase dramatically the vegetation, at least in this region. Some challenges faced during this study include difficulties acquiring the images from EarthExplorer, problems accessing the lab computers remotely, problems with the software and computer crashing, challenges in applying the masks to the images, and issues applying the gridlines to the images. Recommendations for future work include analyzing other areas of Puerto Rico to better understand the effects of the ENSO, as the ENSO does not affect every area equally, acquire images from other dates to compare the changes that occur in other seasons, and utilize a higher spatial resolution sensor to better capture the finer details of the changes in vegetation.

II. Introduction

ENSO is a climate pattern that naturally occurs in the Equatorial Pacific Ocean and is recognized to have worldwide impacts. When ocean surface temperature anomalies are positive, an El Niño phase is occurring. This directly affects the Caribbean by reducing rainfall during the wet season and increasing overall air temperatures. When ocean surface anomalies are negative, a La Niña phase is occurring. This increases the humidity and rainfall the Caribbean receives while promoting lower temperatures. When ocean surface temperatures are average, a neutral phase is occurring. This promotes average temperatures and rainfall in the Caribbean [1]. By analyzing the effects that different ENSO patterns have on the Guánica vegetation, a better understanding of how sensitive the local ecosystem is to these shifts and identify which specific areas are most affected by these patterns and be able to better tackle weather pattern changes in the future.

Year	Month	Monthly Total Precipitation (Inches)
2013	July	2.03
2015	July	0.74
2021	July	0.91

Table 1. Monthly Total Precipitation in inches for the selected dates in the Guánica Dry Forest.

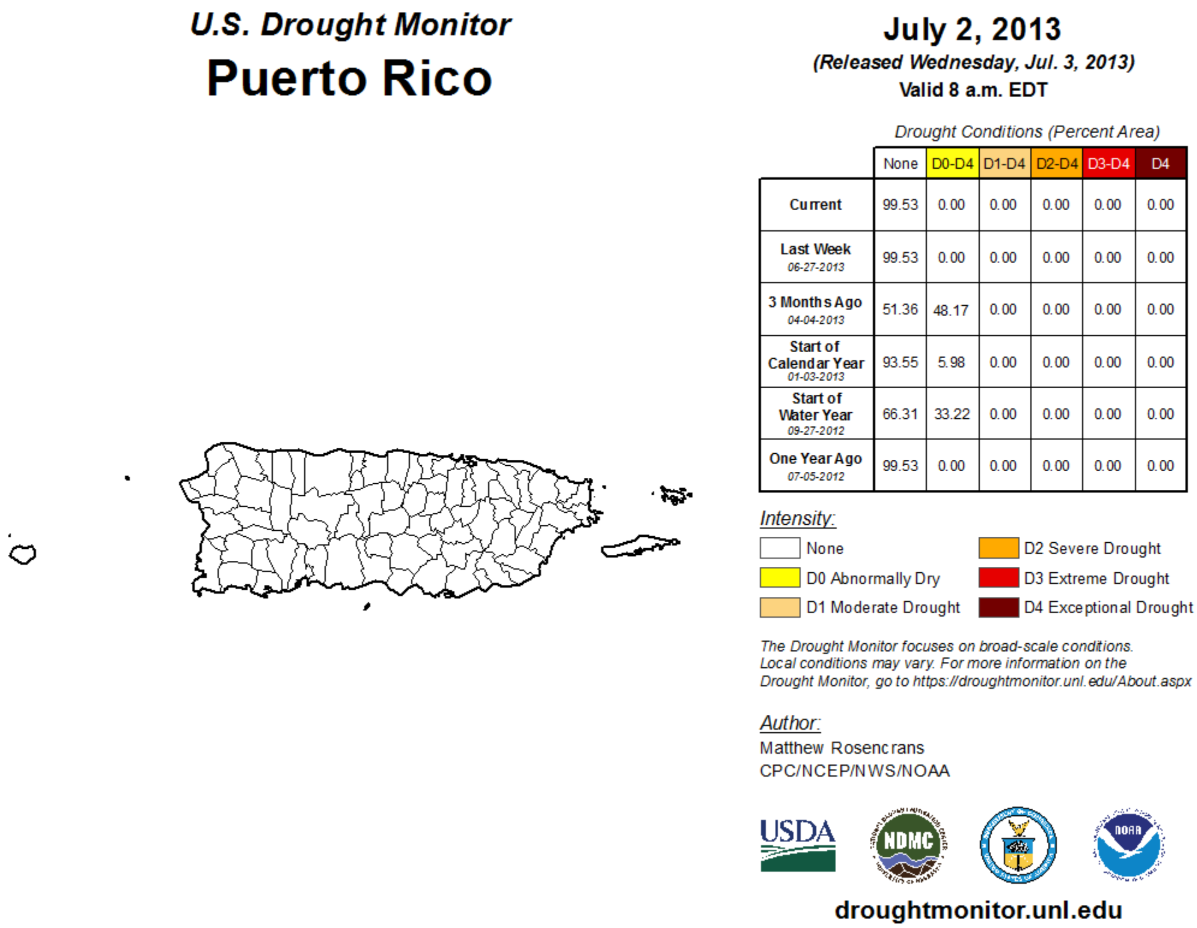

Fig. 1. Drought Monitor for Puerto Rico on July 2, during the 2013 Neutral Phase.

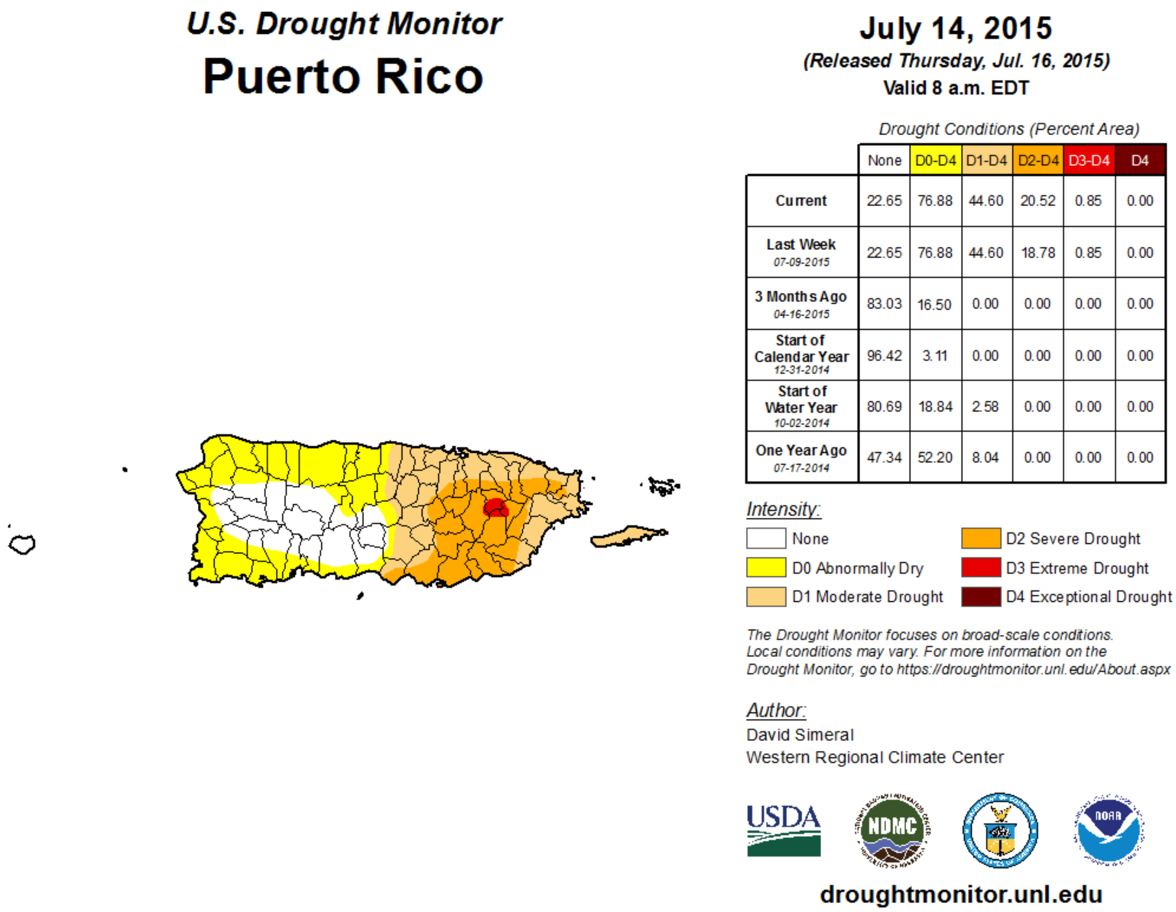

Fig. 2. Drought Monitor for Puerto Rico on July 14, during the 2015 El Niño Phase.

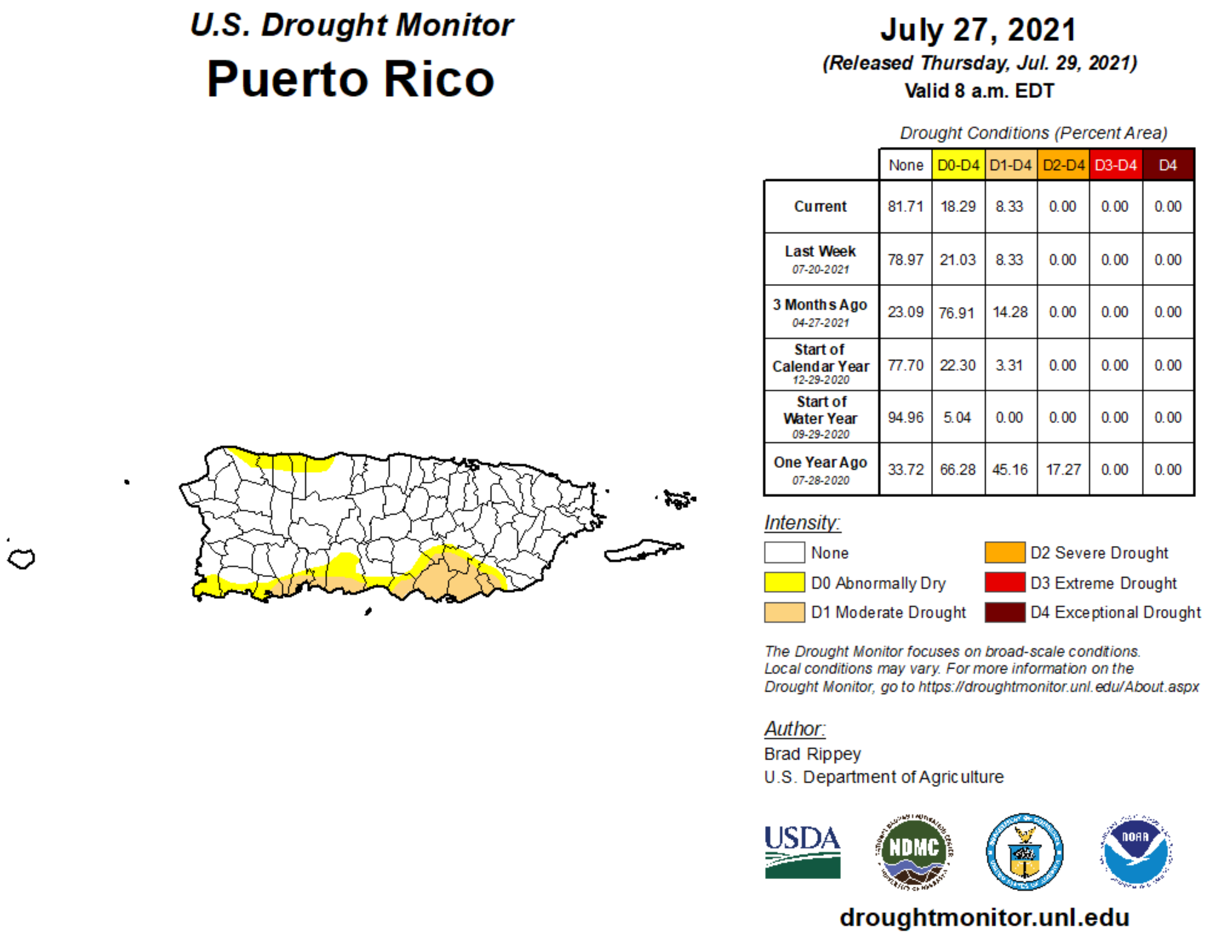

Fig. 3. Drought Monitor for Puerto Rico on July 27, during the 2021 La Niña Phase.

III. Objectives

This study aims Analyze the effects of the El Niño-Southern Oscillation (ENSO) on the vegetation of the Guánica region. Additionally, analyzing these effects will help gain a better understanding of the local ecosystem's sensitivity to these climate shifts and how to prepare for them. Utilizing the neutral phase image from 2013, a baseline will be established using Landsat 8 NDVI to measure the magnitude of vegetation change between extreme climate events. The scientific question to be answered is *How do contrasting ENSO phases (El Niño vs. La Niña) impact the vegetation health of the Guánica region?*

IV. Methodology

The sensor used for this project is the Landsat 8 Operational Land Imager (OLI), which is a multispectral sensor. The OLI captures data with 12-bit radiometric resolution. This allows it to distinguish between 4,096 levels of brightness, which is a massive increase over the 256 levels of earlier 8-bit sensors [3]. This sensitivity, combined with its 30-meter spatial resolution and specialized spectral bands like Near-Infrared (Band 5) and Shortwave Infrared (Bands 6 and 7), makes it an ideal tool for detecting subtle moisture stress and vegetation changes caused by climate cycles like El Niño and La Niña. 3 images were selected from Landsat 8 Operational Land Imager (OLI) for vegetation analysis, ranging from the dates of 2015 which is the image chosen to vibe analyzed from the effects of El Niño 2021 which was chosen to analyze the effects of la Niña and 2013 which is the baseline reference where the weather phenomenon didn't occur. They were taken from July to august from the Collection 2 Level 2 images because they already had undergone atmospheric correction to remove the "noise" caused by aerosols and water vapor, ensuring that the pixel values represent the actual reflectance of the ground. Once the layer stacking was done on the individual spectral bands to create a composite image. For a study on vegetation health, the analyst focuses on the Near-Infrared (Band 5) and Red (Band 4) channels. These bands are then used in a Raster Calculator to compute the Normalized Difference Vegetation Index (NDVI), which highlights the contrast between the chlorophyll absorption in the red spectrum and the leaf structure reflection in the infrared. For the last step the imagery was clipped to the specific study area, such as the Guánica municipality, and a color table were applied to the NDVI results to visually distinguish between the healthy green-up of a La Niña year and the browning caused by an El Niño drought.

V. Discussion

The vegetation index shows substantial changes in vegetation. Through the table (See Table 2). We see that the maximum values are ~1 confirming that no systematic differences in sensor response or processing introduced artificial ceiling effects between years. Since these maximum values are likely to represent a very small number of outlier pixels. We see that as suspected, mean values (0.404) of NDVI of 2015 where El Niño was most active have a significant decrease in vegetation. In 2021 we see an increase in vegetation compared to 2015 This partial recovery is consistent with La Niña's association with above-average rainfall in the region, which would be expected to support greater vegetation vigor than drought-stressed conditions, however it did not show increased levels (0.451) compared to 2013 (0.554) which shows that other external factors influence the vegetation of the surrounding area. The completed NDVI images reflect these values with high vegetation density symbolizing the dark green and low vegetation symbolizing low vegetation density (see figure 6 & 7).

Year	ENSO Condition	Min	Max	Mean	StdDev	Pixel Count
2013	Neutral (reference)	0	0.998	0.554	0.254	113,553
2015	El Niño	0	1	0.404	0.211	113,553
2021	La Niña	0	0.9996	0.451	0.245	113,553

Table 2. Vegetation Index of Guánica from July 2013, 2015, and 2021.

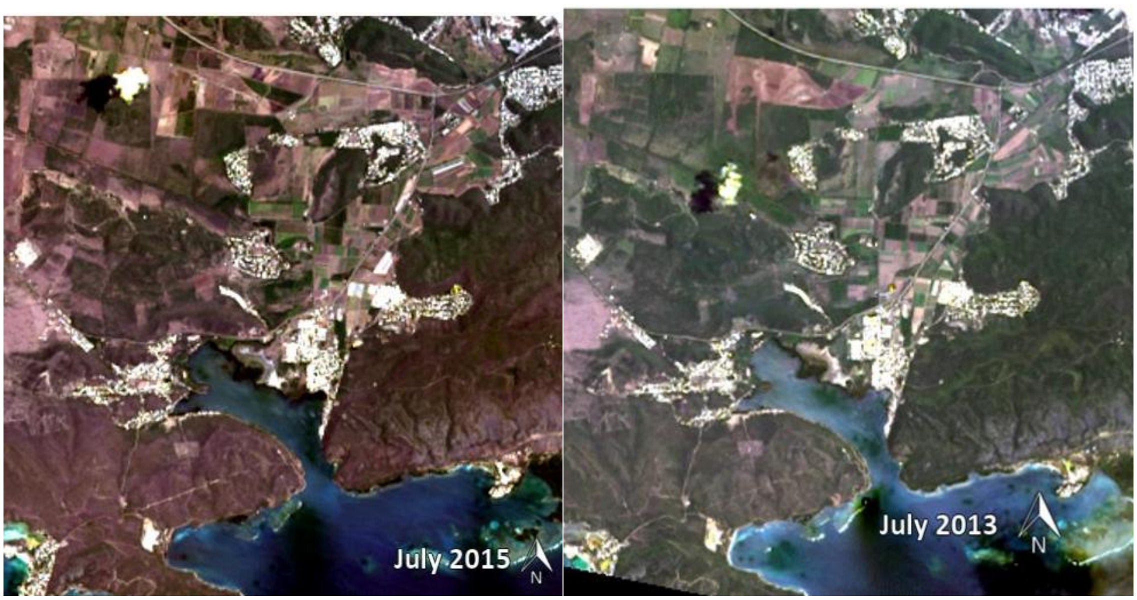

Figure 4. Original images after they were resized, comparing July 2013 vs July 2015.

Figure 5. Original images after they were resized, comparing July 2013 vs July 2021.

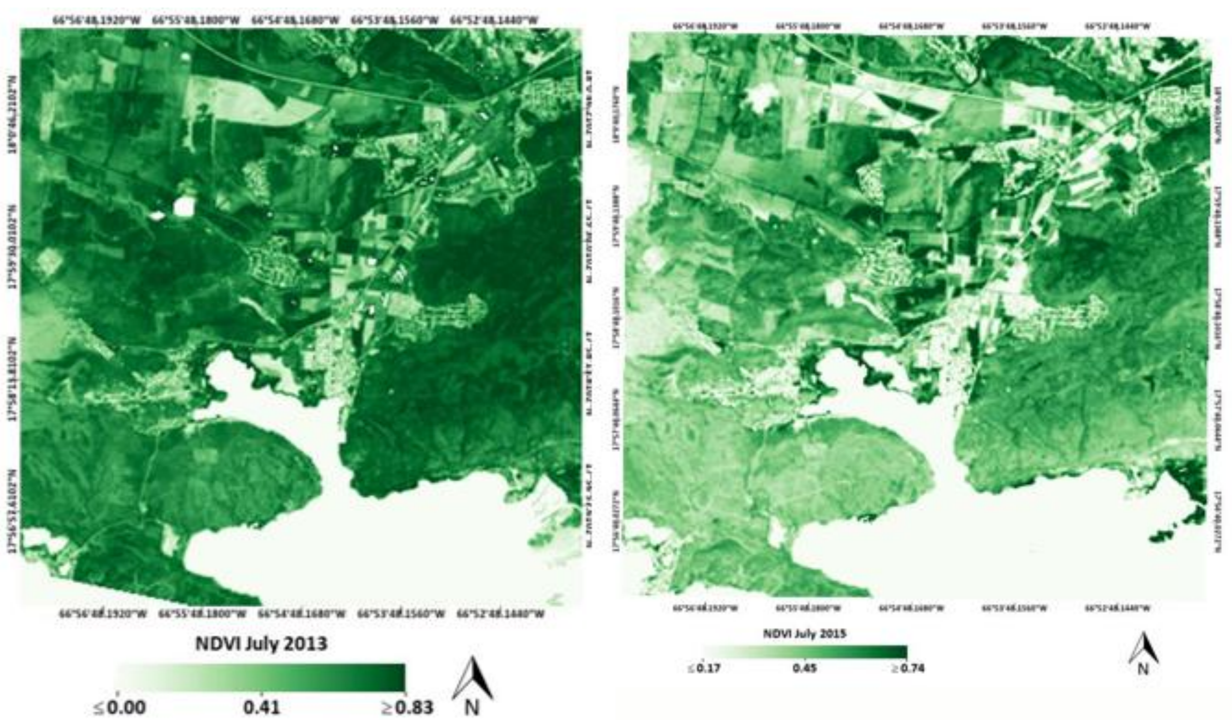

Figure 6. NDVI values comparing July 2013 vs July 2015.

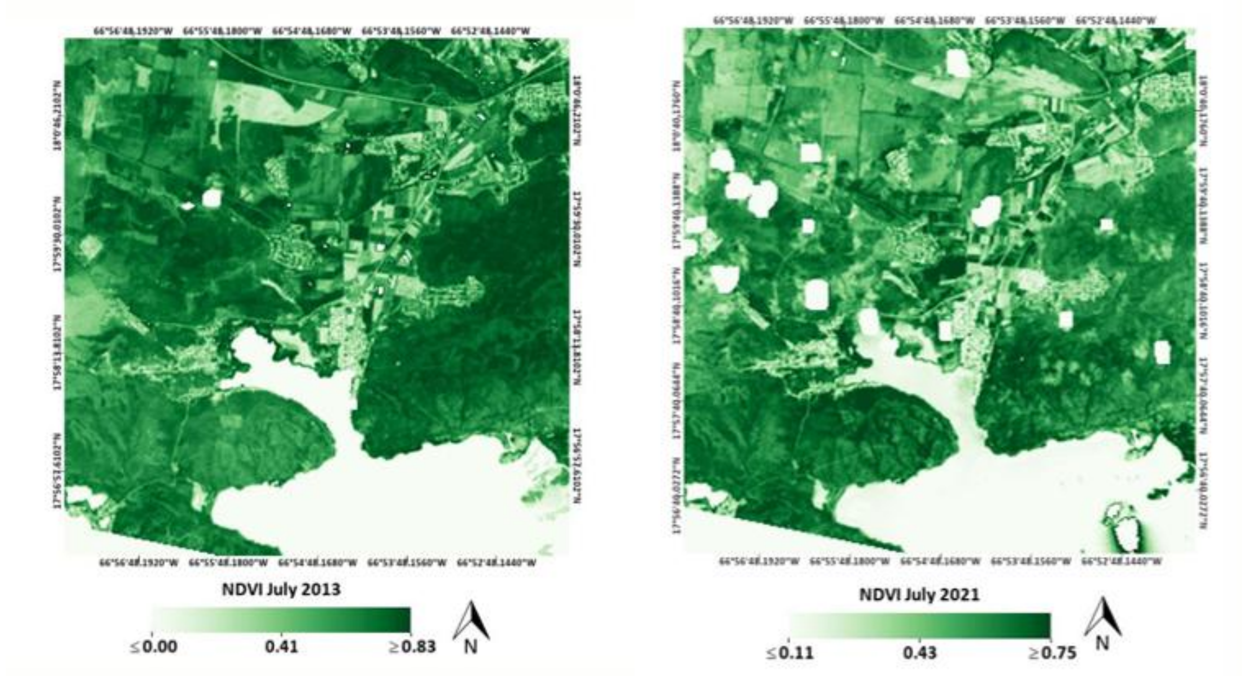

Figure 7. NDVI values comparing July 2013 vs July 2021.

VI. Problems

During the study some significant challenges were faced including difficulty finding and downloading the images to use for the study, issues accessing the lab computer remotely as there was no access to the university, problems with the computer and ENVI crashing as the computing resources were not sufficient, and difficulties applying the mask and gridlines to the NDVI image as the gridlines were too large and the values to mask the water were unknown.

VII. Conclusion

This study examined the influence of ENSO (El Niño-Southern Oscillation) on vegetation dynamics in the Guánica, Puerto Rico. Analysis of vegetation index data revealed measurable changes across both El Niño and La Niña phases, indicating that ENSO plays a meaningful role in shaping the ecological conditions of this dry forest ecosystem. These findings contribute to a broader understanding of how large-scale climate phenomena drive vegetation responses in tropical dry forests, which are among the most climate-sensitive ecosystems in the Caribbean.

This study was limited in geographic scope, focusing solely on the Guánica, and the time periods analysed may not capture the full range of ENSO variability. Future research should expand to other regions of Puerto Rico and incorporate a wider range of dates to more accurately characterize the spatial and temporal effects of ENSO on island vegetation. Such efforts would help build a more comprehensive picture of climate-vegetation interactions across diverse Puerto Rican ecosystems.

VIII. Recommendations

To improve future studies of the ENSO effects in Puerto Rico, the investigators should include other areas of Puerto Rico to better understand the effects of La Niña and El Niño in the vegetation, as the effects are different depending on the area. Additionally, analyzing other dates from the ones chosen in this study will improve the understanding of the ENSO effects in the region by analyzing the different variability in the seasons that can occur because of the ENSO effects. Furthermore, utilizing a higher spatial resolution sensor will improve the detection of the small changes that occur in the vegetation in contrasting ENSO phases.

IX. References

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