Remote Sensing Phenology

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Introduction

Remote sensing can be defined as the process of detecting and monitoring the physical characteristics of an area by measuring its reflected and emitted radiation at a distance. Special cameras collect remotely sensed images, which help researchers acquire a unique perspective of the planet and allow for regular, even daily, monitoring of the entire global land surface. Some specific uses of remotely sensed images of the Earth include:

1. Mapping Large forest fires thus allowing rangers to see a much larger area than from the ground
2. Track erupting volcanoes
3. Track the growth of a city and changes in farmland or forests over several years or decades
4. Among others

The use satellite sensors for monitoring phenological events have relatively large "footprints" on the land surface, they gather data about entire ecosystems or regions and because data collection by satellite sensors can be standardized, the data are reliably objective.

Phenology is the study of plant and animal life cycles in relation to the seasons. Plant phenology measurements track sensitive and easily observed indicators of biotic responses to climate variability by recording and monitoring the timing and duration of phenological stages in plant communities. Recording of changes show seasonal progression of critical biological processes and the timing of ecological events and seasons.

Remote sensing phenology is defined as the use of satellites to track phenological events and complements ground observation networks. It can reveal broad scale phenological trends that would be difficult, if not impossible, to detect from the ground. Because phenological events are sensitive to climate variation, these data also represent a powerful tool for documenting phenological trends over time and detecting the impacts of climate change on ecosystems at multiple scales.

The study site selected is the Guanica Dry Forest, located in the southwest side of the island. According to Monsegur (2009) the annual rainfall can be up to 30 inches but can fluctuate between 25 "to 40". Rainy season has been identified to be from August to November and the dry season is from December to April. Temperatures fluctuate from 75F to 82 with a maximum temperature of 100F in the most exposed areas and a relative humidity of about 65 to 80%. The predominant soil has a formation of sedimentary rocks, mainly limestone. The dominant vegetation is a small and dense forest of trees and shrubs that generally do not exceed five meters in height, although some of these trees can reach 10 to 15 meters. The forest is mainly composed of deciduous forest and evergreen forest.

During the goal setting of this research project I was planning to develop an elevation model of the phenology plot and the Guanica Dry Forest by using LiDAR point cloud data provided by the NEON project but during the processing of the data I encountered several problem when attempting load lidar files into the geodatabase using the LAS to Multipoint tool I noticed that the classification values were not assigned. According to the ESRI manual for processing LiDAR data, datasets captured will often contain the classification in the metadata that is associated with lidar data but this was not the case and due to time constrains, the goal of this research was modified.

Scientific Question

Can we observe phenological events and patterns thought the combination of in-situ phenology measurements and NDVI remote sensing data?

Objectives

The primary objective of this investigation is to understand how different types of data can be used to understand phenology patterns in nature, as well as to integrate diverse methods of analysis.

This research intends to:

- Calculate patterns in phenophases using RStudio
- Create study site map using GPS ground data and Orthomosaic Imagery.
- Calculate Vegetation Index (NDVI) for the study area using 2 for two individual months images from each year (2016,2017,2018) in ArcGIS.
- Compare NDVI results with observational data from selected phenophase observations

Methodology

The National Ecological Observatory Network established a plot with 800m transect were a primary selection 3 more common species (previously determined by other research) were selected in 2015-2016 with a total of 10 individuals. Later, further selection was carried on by adding a third species to the list with a total of 90 individuals (30 individuals per species) from 2017 to present.

The species selected were *Pisonia albida* (commonly known as corcho bobo), *Gymnanthes lucida* (yahiti) and *Bursera simaruba* (almacigo). Phenological observations are made once a week according to specifications from the NEON project and data is available in the data portal for free. GPS points for each of the individuals observed were collected. The image used for the creation of the map was downloaded, from the NEON data portal, by using UTM coordinates to identify the study area.

In order to create the map, the following procedure carried out:

1. Create an excel database with four columns (Latitude, Longitude and Category).
    a. Save as 97-2003 Workbook format.
2. Open a Blank Map in ArcMap.
3. Add the Tiff format picture of the study area.
4. Add the excel file with coordinates.
    a. Open the table and select “Display XY Data”.
5. Export GPS data to a shapefile and add a new column with descriptions of the points.
6. Change the symbology of the points.
    a. Individualize each symbol according to what it represents
7. Insert a north arrow
8. Insert a scale Bar
9. Insert a title and description

The next step of the research project is to download the observational data from the data portal and use an R script written specifically to analyze the total number of individuals that presented a specific phenophase for the years 2016, 2017 and 2018.

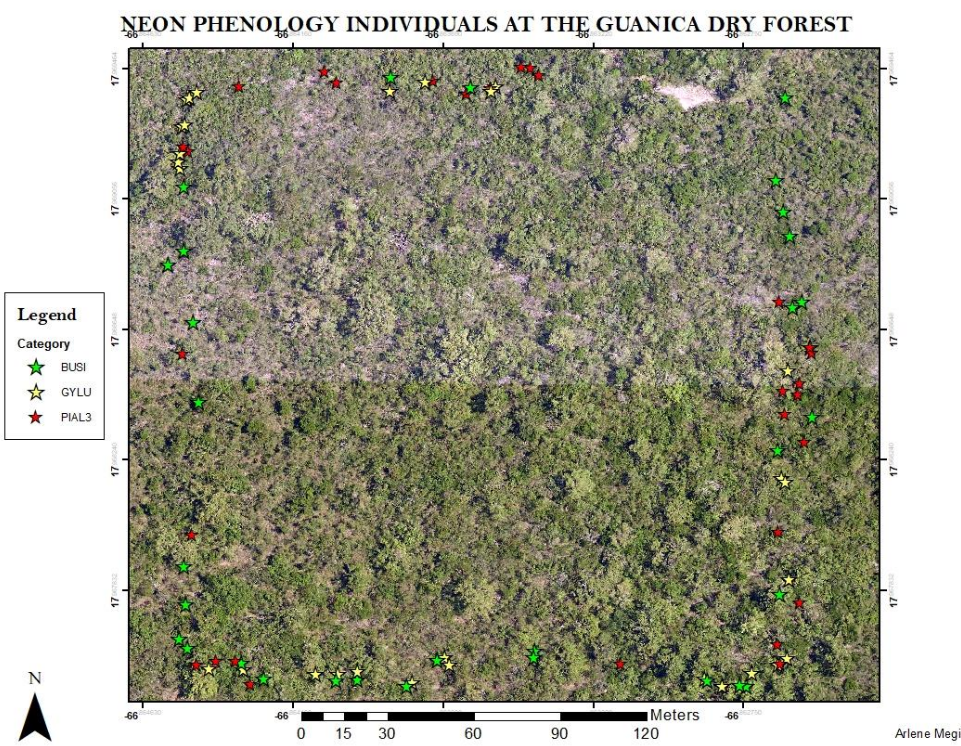
The last step was to calculate the vegetation index in the study area for 2016, 2017 and 2018 and selecting two images, one from a dry month and one for a wet month. The following procedure was carried out:

Image Acquisition
1. Download images from the EarthExplorer website.
2. Unzip the downloaded file (.tar or .gz) using an unzip program.

Image Processing
1. Open the OLI MTL file in ArcMap
2. Make a sharpening using the panchromatic band (B8) and save
3. Calculate the NDVI of the hi-resolution image using the Image Analysis tools
4. Add the Municipalities layer
5. Select the study area and perform the analysis of changes in NDVI

Results

Map Creation



R analysis results

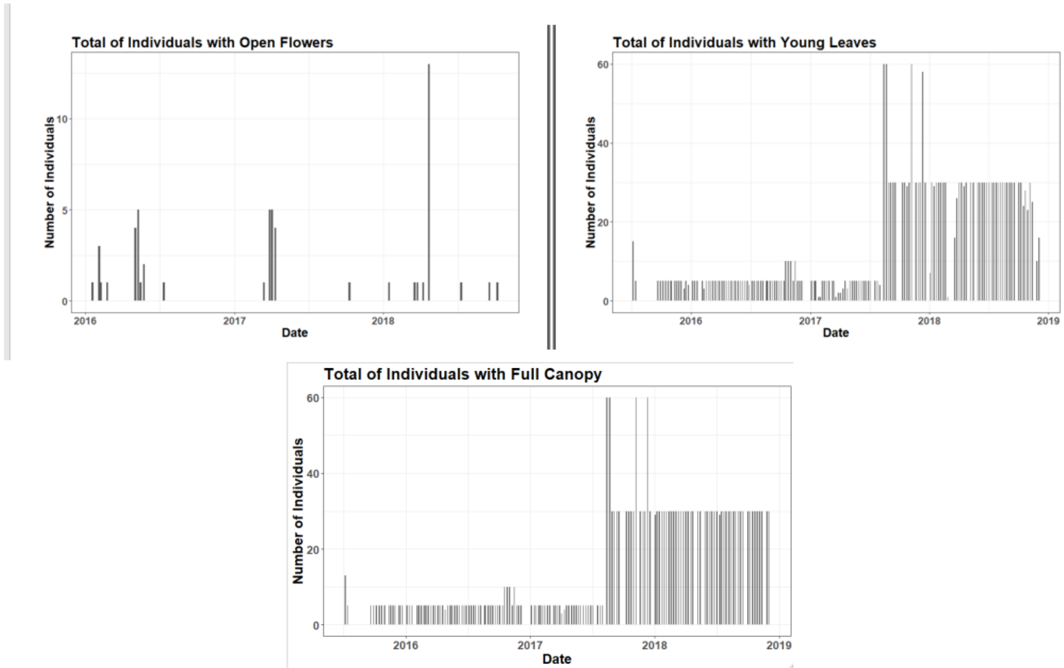


Figure 1 Pisonia albida

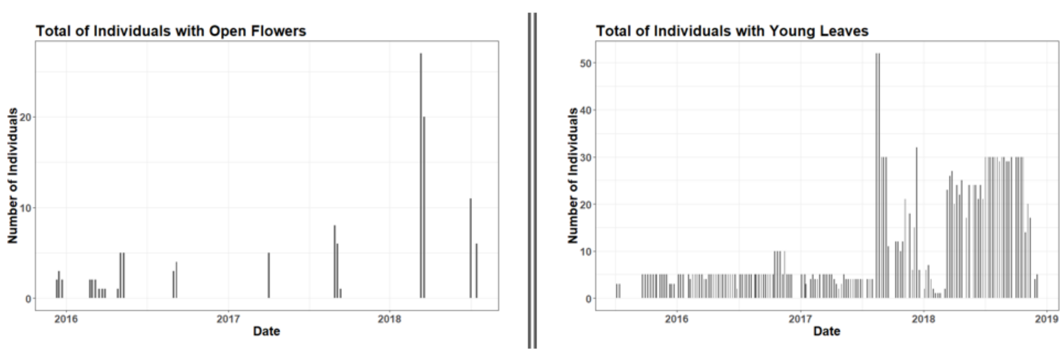


Figure 2 Gymnanthes lucida

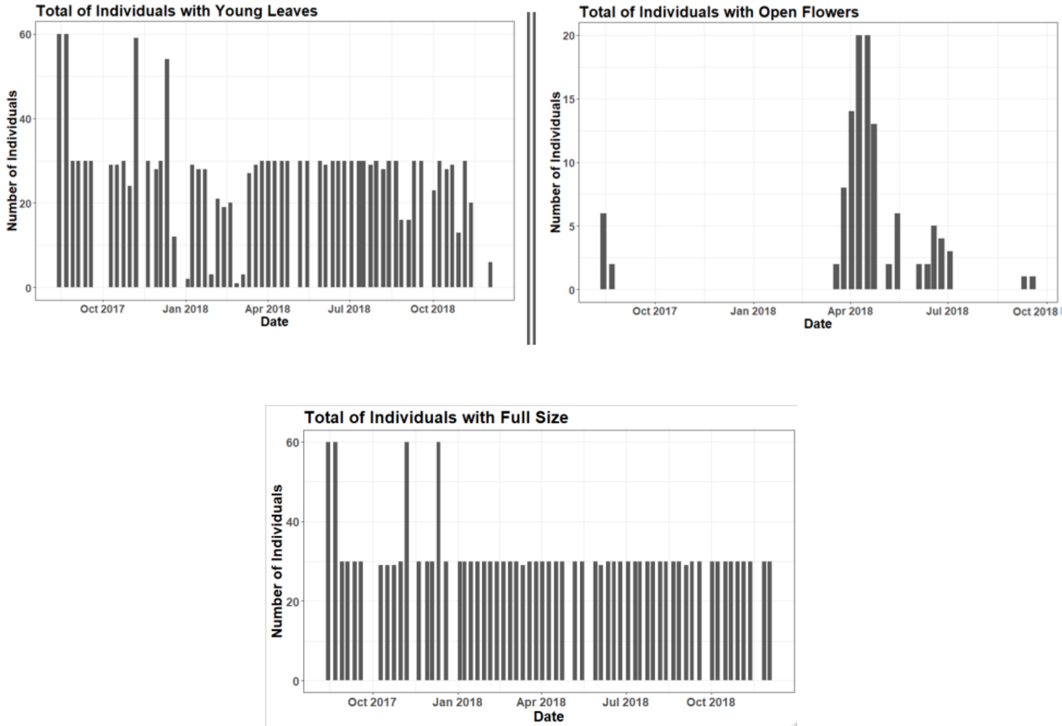
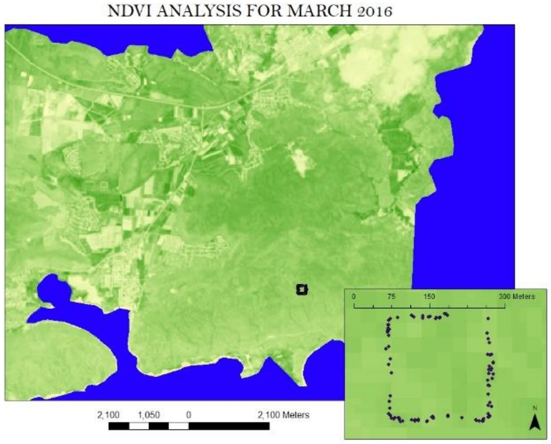


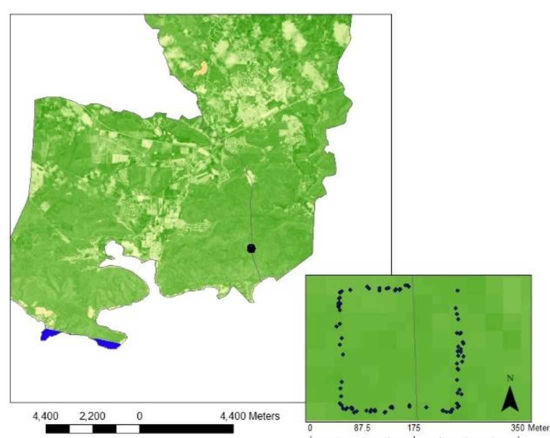
Figure 3 Bursera simaruba

NDVI FAILED results

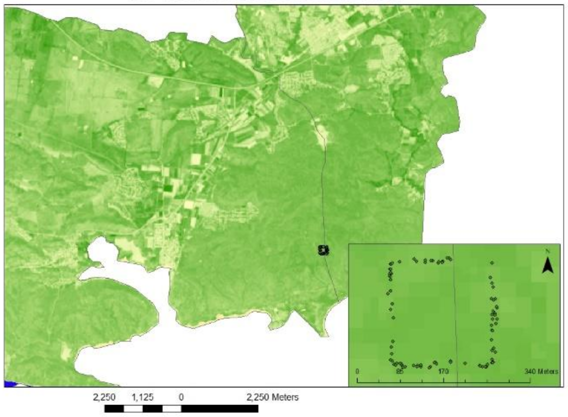
NDVI ANALYSIS FOR MARCH 2016



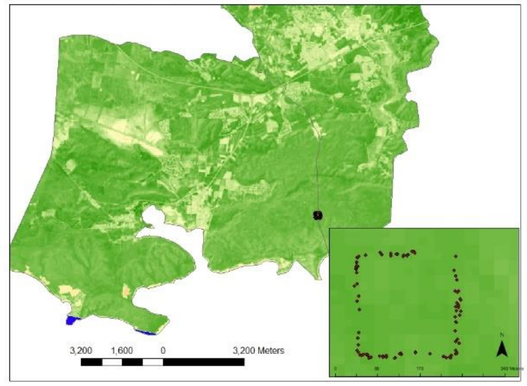
NDVI ANALYSIS FOR OCTOBER 2016



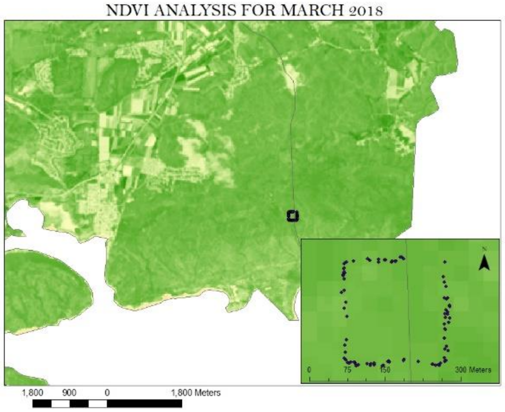
NDVI ANALYSIS FOR APRIL 2017



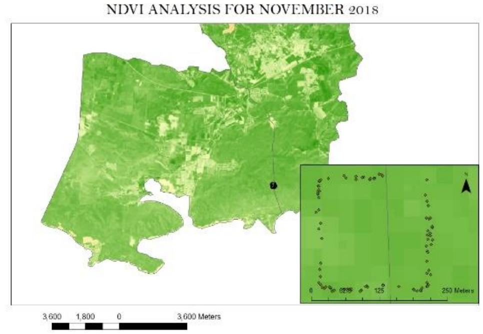
NDVI ANALYSIS FOR NOVEMBER 2017



NDVI ANALYSIS FOR MARCH 2018



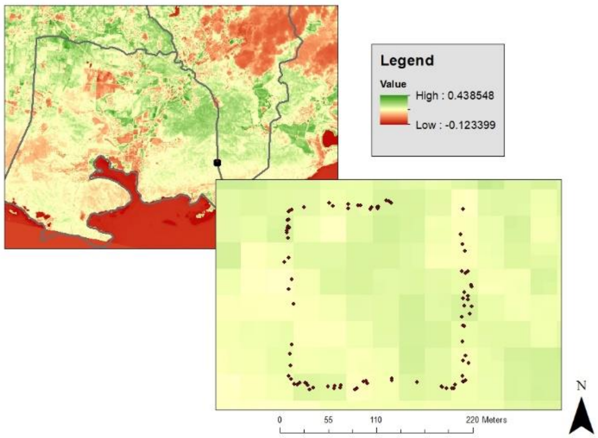
NDVI ANALYSIS FOR NOVEMBER 2018



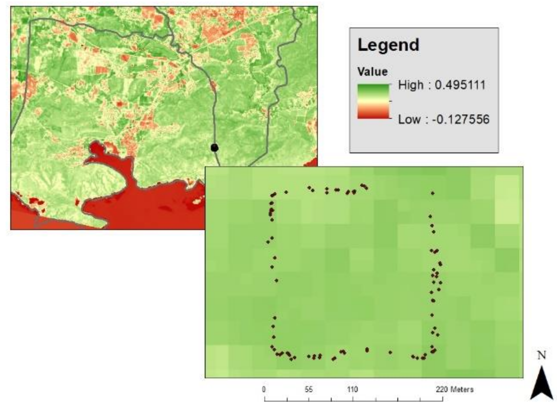
These results are included in this written report because upon re processing the images, we noticed that the NDVI results were not being calculated properly. This may be a result of either not including the scientific output option or failed process of pan sharpening. The next section will present corrected images and discussion is based on them.

Corrected NDVI Results used for discussion

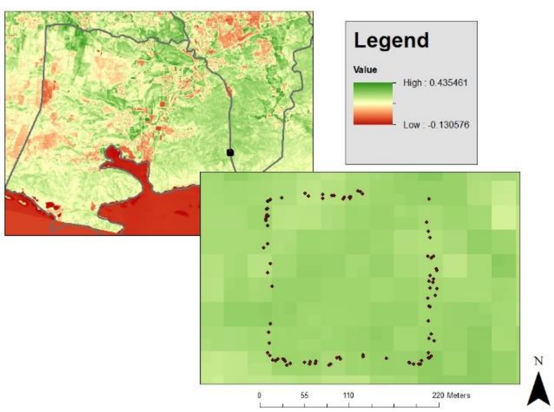
NDVI ANALYSIS FOR MARCH 2016



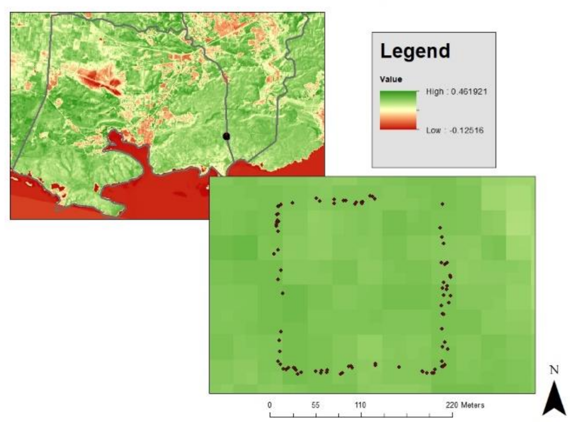
NDVI ANALYSIS FOR OCTOBER 2016



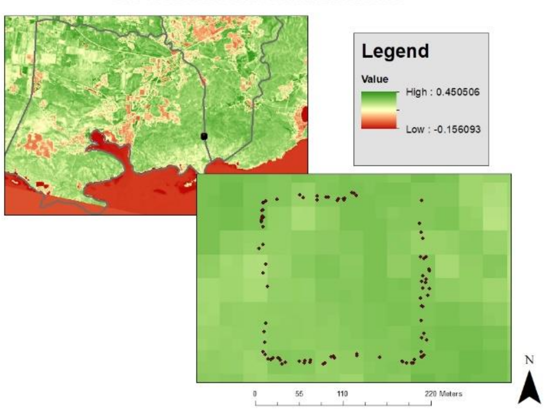
NDVI ANALYSIS FOR APRIL 2017



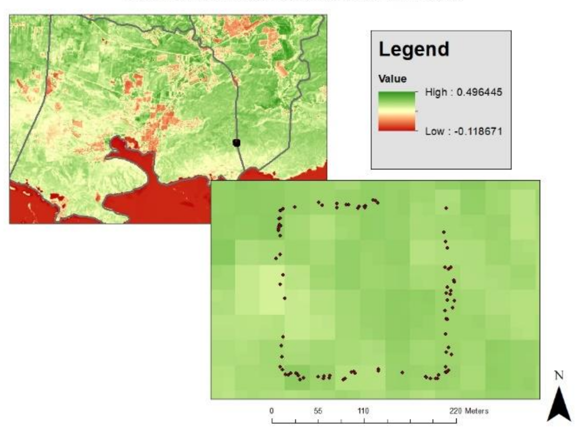
NDVI ANALYSIS FOR NOVEMBER 2017



NDVI ANALYSIS FOR MARCH 2018



NDVI ANALYSIS FOR NOVEMBER 2018



Discussion

R analysis show an increase in phenophase observations (young leaves, open flowers, and full canopy) by individuals during the raining season for *Pisonia albida*. Similar behavior can be observed in the *Bursera simaruba* species although observations date after 2017. For *Gymnanthes lucida* observations only include flowering and young leaves and a pattern consistent with wet season can be observe. It should be noted that *Pisonia albida* and *Bursera simaruba* are deciduous broadleaf and *Gymnanthes lucida* thus observation requirements differ to accommodate forest behavior.

NDVI analysis for the year 2016

March image shows NDVI results ranging (when identified tool used) values from 0.1-0.2 near the selected individuals and an overall high value of 0.438 and a low value of 0.123 for the whole polygon. While NDVI results for October, image shows pixel values that range from 0.2-0.3 (higher than the previous evaluated month) in the selected individuals with a similar high and low values for the whole polygon.

NDVI analysis for the year 2017

April image shows NDVI results (when identified tool used) with a constant value of 0.2 near the selected individuals and an overall high value of 0.435 and a low value of 0.130 for the whole polygon. While NDVI results for November, image shows pixel values that range from 0.2-0.3 (higher than the previous evaluated month) in the selected individuals and an overall high value of 0.461 and a low value of 0.125 for the whole polygon.

NDVI analysis for the year 2018

March image shows NDVI results (when identified tool used) with a constant value of 0.2 near the selected individuals and an overall high value of 0.450 and a low value of 0.156 for the whole polygon. While NDVI results for November, image shows pixel values very similar to the previous image in the selected individuals and an overall high value of 0.496 and a low value of 0.118 for the whole polygon.

Overall

Results suggest some similarity to what is being observed during in-situ observations although further study must be made comparing the same day of a marked observation with a satellite image. Results also suggest that values from the year 2018 may be similar due to the area’s response to the natural disaster of the previous year.

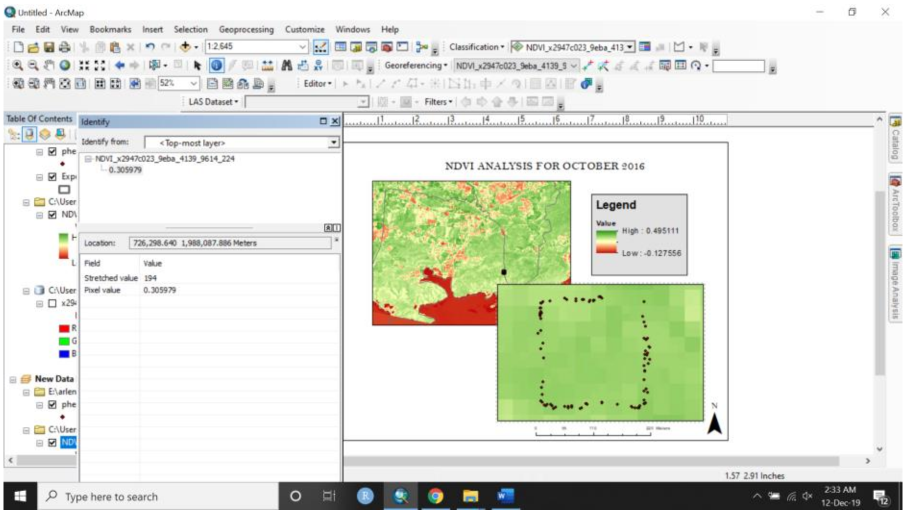
Conclusion

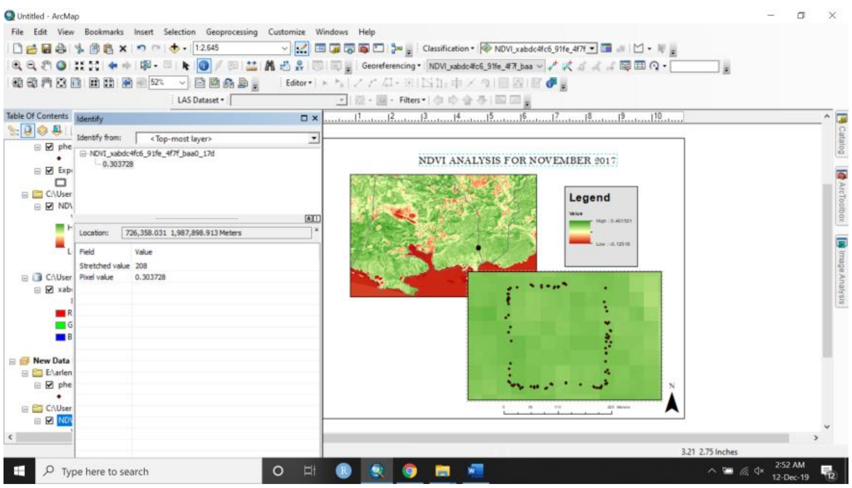
During different seasons, plants exhibit changes in patterns and stages that can be observable and quantified. For example, observable data shows an increment in flowers and young leaves production between late 2017 until October 2018 thus marking a shift in phenophases. These shifts can also be observed through the changes in pixel cells surrounding the GPS point after an NDVI adjustment.

Recommendations

1. Precipitation and Temperature data from NOAA
2. Selection of months to download images based on precipitation data (dry to wet)
3. LiDAR Canopy and Elevation Models
4. More images with better resolution
5. SAVI Calculations
6. Pixel numerical validations by table

Example of NDVI results using identify to evaluate pixel value





References

- Alekhin, S. I. (2001). Impact of the three-loop corrections on the QCD analysis of the deep-inelastic scattering data. *Physics Letters, Section B: Nuclear, Elementary Particle and High-Energy Physics*, *519*(1–2), 57–62. https://doi.org/10.1016/S0370-2693(01)01090-5
- Jones, K., Elmendorf, S., & Krauss, R. (2018). TOS protocol and procedure: Plant Phenology, 1–117.

- Jones, M. Data Tutorial: Work with NEON OS & IS Data – Plant Phenology & Temperature. Accessed: March 26, 2019. National Ecological Observatory Network, Battelle, Boulder, CO, USA.
- Kolterman, D. A., Breckon, G. J., Aponte, N. E., & Carlo, N. D. (2009). VASCULAR FLORA OF THE GUÁNICA DRY FOREST, PUERTO RICO
- National Ecological Observatory Network. 2019. Data Products: NEON.D04.GUAN.DP1.10055.001. Provisional data downloaded from http://data.neonscience.org on February 26, 2019 Battelle, Boulder, CO, USA
- U.S. Geological Survey (2016) 'Puerto Rico.' Available at http://earthexplorer.usgs.gov [Verified 02 December 2019]
- U.S. Geological Survey (2017) 'Puerto Rico.' Available at http://earthexplorer.usgs.gov [Verified 02 December 2019]
- U.S. Geological Survey (2018) 'Puerto RIco.' Available at http://earthexplorer.usgs.gov [Verified 02 December 2019]