Moisture mapping of the Puerto Rico Western area using Landsat data

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Introduction

One of the main components in agriculture is water. Climate changes can affect the availability of water and in turn affect crops. It is important to know the water content in plants to schedule efficient watering. Know the available water content in the soil for water. Currently, several methods are used in situ for this purpose. Although, new technology in remote sensing to study the water content in plants. For example, vegetations indexes are calculate using image satellites and images from unnamed aerial vehicle (UAV). Two examples of vegetation index are the Normalized Differences Moisture Index (NDMI) and the Moisture Stress Index (MSI).

The Normalized Difference Moisture Index (NDMI) is an index that monitors crop moisture and determinate areas with water stress. This index can be used for advance harvest logistics because it can differentiate between the moisture content of soil and vegetation. For this index the interpretation is divide it by higher values that confirms more moisture content and by lower values that confirms lower moisture content. Sarif, Rimal and Stork (2020) demonstrate the negative correlation between this index and the Land Surface Temperature (LST) in decades intervals (1988, 1998, 2008, 2018) in Kathmandu Valley (Nepal). Where when a reduction in moisture content resulted in higher LST and the agriculture had effects on the LST distribution. In addition, this index is very useful on the image analysis. The NDMI was the more accurate index on the analysis of hurricanes effect and seasonal events on mangroves (Zhang et al, 2016). Compared with other indexes like SAVI and EVI.

Another example of vegetation index, the MSI is used to predict crop productivity and analyzed canopy stress. This index uses the detection of the leaf water content. The MSI had higher values when the plant had water stress and lower values when the plant had the adequate moisture content. The index had an inversely relationship with other indices, when had higher values there is water stress and with lower values the adequate moisture content. The MSI was used to establish a relationship with MSI and the soil moisture percentages at Soil Climate Analysis Network (SCAN) in Alabama counties (Welikhe et al., 2017). However, the correlations decline the MSI increasing values. Also, this index was used for monitored the Mountain Pine Beetle (MPB) attack in forest . Where it was confirmed that this index can be used to analyze the forest change through the year.

In this project, a comparison through year in the NDMI and MSI, Lastly, compare the images regenerated between this two indexes.

Scientific question

- Can two indices be correlated adequately for a specific area?
- Will there be an index with which the data is better represented on a map?

Objectives

- Calculate the Moisture Stress Index (MSI) and the Normalized Difference Moisture Index (NDMI)
- Observe the moisture distribution across the selected area
- Compare the two moisture indices in the study area

Methodology

The study location of this project was the western area of Puerto Rico. This area includes the following municipalities: Aguadilla, Aguada, Moca, Rincón, Añasco, San Sebastián, Las Marías, Mayagüez, Maricao, Hormigueros, San Germán, Sabana Grande, Cabo Rojo and Lajas. Satellite images were used in this project from https://earthexplorer.usgs.gov/ . Four images from the 2019 year for a comparison through time. The Landsat 8 was used to download the images in tar file and then converted to zip file for future analyzed.

In the computer, the ArcMap program was open and the folders where the images were located were connect. Then the images of bands 5 and 6 were added. To begin the processing, the Arctoolbox tool was located, the spatial analyst option was searched, and the map algebra tool was selected. The MSI equation was entered: $\frac{B6}{B5}$ and click ok on it. A new image of the calculation appeared. Then a shapefile of the municipalities of Puerto Rico was added to the work and the municipalities of interest are selected. With this selection of features, a new layer of the selected features was created. A new layer appeared in the workbook with the selected municipalities. The data management tool was searched, then the raster option and clip were selected. The input raster was the image with the calculation of the index, the output extent was the layer of the municipalities of interest and the box of use input features for clipping geometry was checked and ok was selected. A new image was generated with the municipalities of interest and the MSI calculation, on the properties option in the symbiology area, 4 intervals were selected to generate the data categories in the image. In the ramp color area, the desired color

ramp was selected. The image with the new color scale was updated. Then the map was prepared with the elements of title, legend, and scale.

This same procedure was repeated with 4 images for the MSI index. Finally, the same procedure was carried out, but with the NDMI and its formula is $\frac{B5-B6}{B5+B6}$, and with three additional images. When all the images were obtained, a comparison between the index was made.

Results and discussion

For the first part of this project, the NDMI, in Figure 1 was observed the moisture development through this area during the 2019 year. For the month of January, the image was taken on January 10, 2019, and had a range of values for this index from -0.0674 to 0.5048. The area was moist, with slightly dry and dry parts in the southern area. For example, between the Lajas and Cabo Rojo towns. In addition, a small coastal area of Aguadilla looks dry.

For April, the image was taken on April 16, 2019. It has a range of values between -0.0907 and 0.5766. The area was mostly moist, with slightly dry and dry parts in the southern area, between Lajas and Cabo Rojo towns. More slightly moist part was observed. On August 22, 2019, the August image was taken. With values ranging from -0.1591 to 0.5794. The area was almost completely moist. A major slightly dry and dry parts in the southern area. Lastly, for the December image, the image was taken on December 28, 2019, with values ranging from -0.0487 to 0.4581. Most of the area was moist and more distribution of slightly moist and dry parts in the southern area. A small coastal area of Aguadilla, San Sebastian and Mayaguez looks dry.

In general, the NDMI values range are -1 – 1. This index is sensitive to water content changes in vegetation canopy. On these data, there was variation between the selected dates, the low values range were -0.1591- -0.0487, and the high values ranges were 0.4581 – 0.5794. August was the month with more slightly dry and dry parts (had low values) and January was the month with higher moist part. Although August was the month with more very moist parts (had high values).

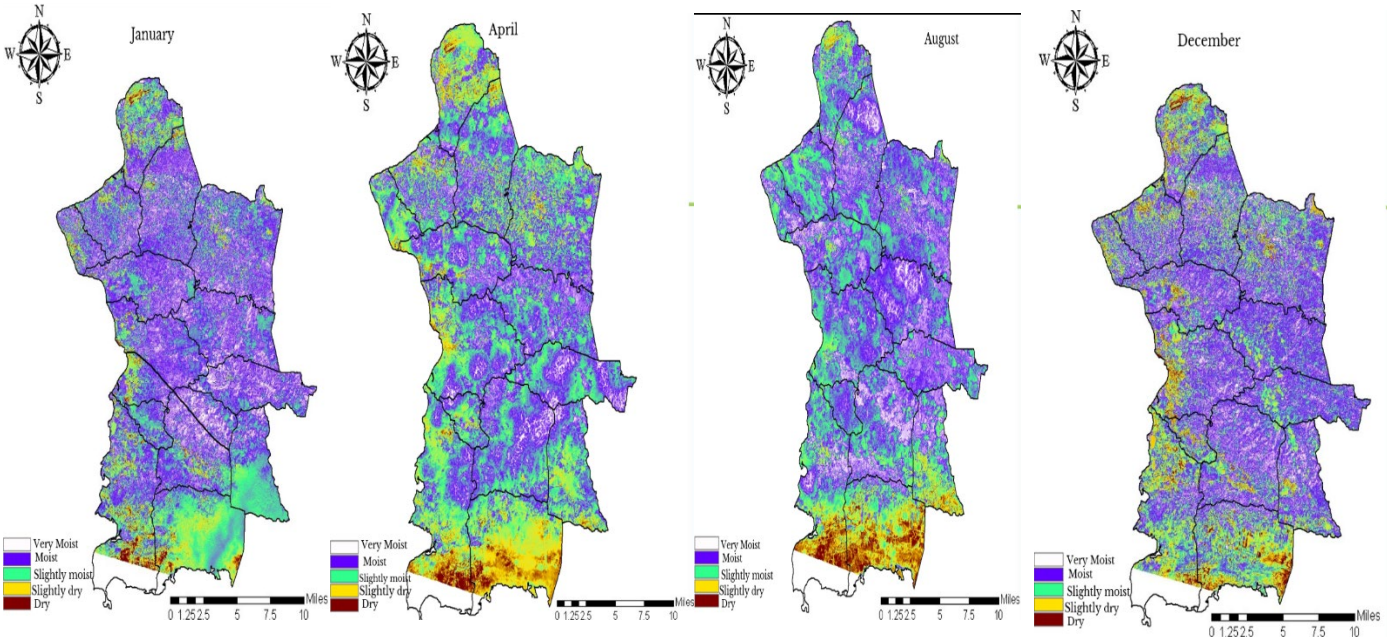

Figure 1. Norm. zed Difference Moisture Index (NDMI) from the Western area of Puerto Rico throughout the 2019.

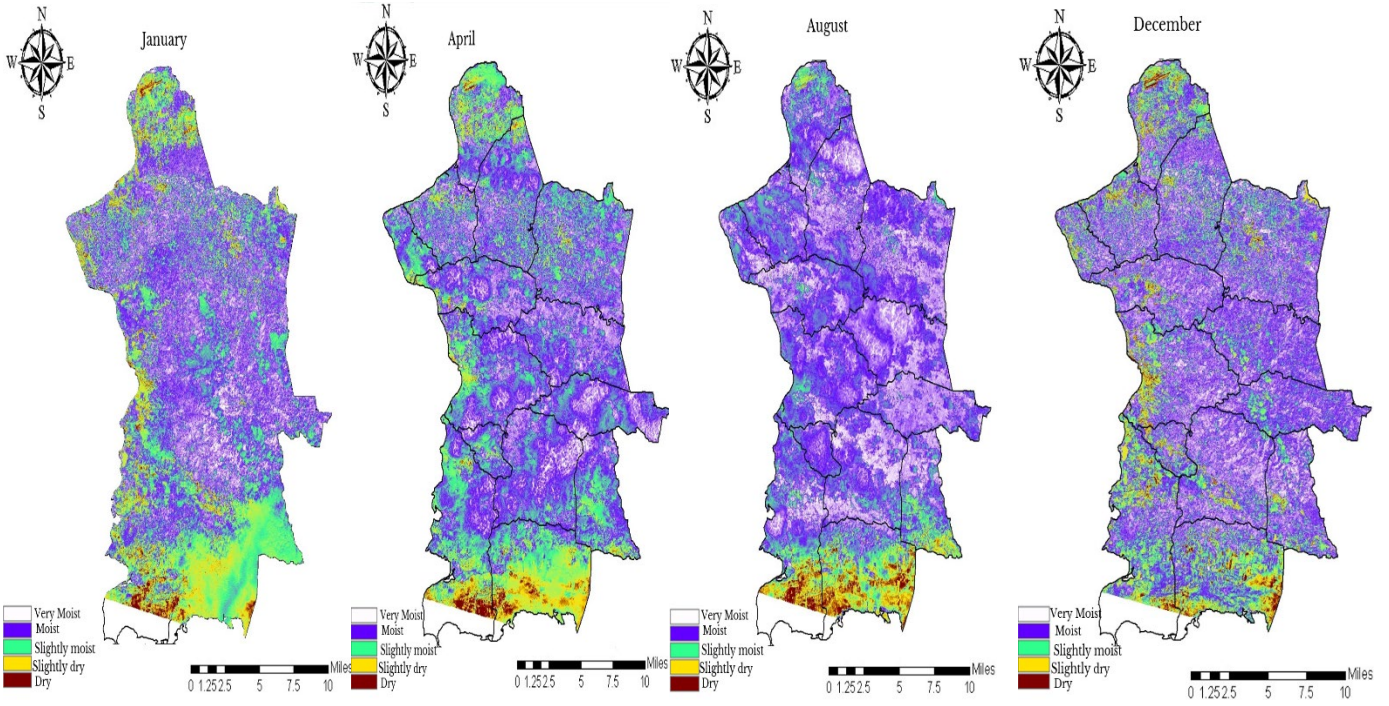

Figure 2. Moisture Stress Index (MSI) from the Western area of Puerto Rico throughout the 2019.

For the second part of this project, the MSI, in Figure 2 was observed the moist development through this area during the year 2019. For the month of January, the image was taken on January 10, 2019, and has a range of values for this index from 0.4964 to 1.6678. The Lajas, Sabana Grande and San German have a greater moisture variation than the other areas. For example, between the Lajas and Cabo Rojo towns were slightly dry and dry parts.

For April, the image was taken on April 16, 2019. It has a range of values between 0.4548 and 1.5573. the area was mostly moist. In Cabo Rojo there was a considerably dry area. A slightly dry zone was at Lajas. On August 22, 2019, the August image was taken. With values ranging from 0.4194 - 1.6661. There were areas moist and very moist closed to each other. The southern area was mainly dry and slightly dry. Lastly, for the December image, the image was taken on December 28, 2019 with values ranging from 0.4908 - 1.5449. The area was mostly moist. Lajas, Cabo Rojo, Mayaguez, Añasco and Aguadilla have slightly dry and dry parts.

In general, the MSI values range are from 0 to more than 3. This index is sensitive to water content increases in the leaf. This index is inversely related to other water vegetation index. On these data, there was variation between the selected dates, the low values range were 0.4194 - 0.4964 and the high values ranges were 1.5449 - 1.6678. August was the month with more slightly dry and dry parts (had low values). April was month with higher moist par, but August was the month with more very moist parts (had high values).

In the last part of this project, the comparison between the two indices. In January, both indices have similar moist areas. Although, more moisture parts were observed with the NDMI. With the MSI a greater slightly moist part were observed. On April, with the NDMI, more slightly moist, slightly dry, and dry parts were observed. Although, the MSI has a greater moist and very moist area. On August, the NDMI had a slightly moist, slightly dry, and dry areas on the southern area. With the MSI, a more very moist and moist area were observed. Lastly, on the last image (December), at firs look, there were no differences between these two images. With a closer look, the differences were observed on the Aguadilla, Hormigueros and Cabo Rojo towns. Were a slightly moist and slightly dry areas were observed with the NDMI. The MSI is sensitive to leaf water content while NDMI is sensitive to vegetation water content; both analyzed the moisture of plants. Alvino et al. (2020), showed high correlation between them describing the moisture.

Project Limitations

The limitations of this project were: couldn’t perform a pan sharpen with the band images selected, the images were cut in the southern part area and values range weren’t the same for all images.

Conclusions

In this project, there were two scientific question to answer. The first one, was clearly answer; both indices can be visually correlate with a color scale in a specific area. While the second one, was not answer. The data obtained in this project could not answered this question because visually there were no significant differences between the indices. While the objectives for this project were completely met. From this study it can be observed that there are different methods to analyze the same measurement, even using the same bands to calculate them. Also, the importance of making the correct formulas for the indices and identifying the ranges of values correctly with the colors.

Recommendations

Find a procedure that allows pan sharpen o the band images. Realize this project in a more specific place, for example, a farm. Use a UAV (unnamed aerial vehicle) with a multispectral camera to take images of the area. Lastly, use the same values ranges in the processed images.

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