Changes in Forest Cover in the West Amazon Rainforest

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Objective

The objective of this project is to utilize geographic information systems technology to track deforestation in the Amazon Rainforest in midwestern Brazil. Agribusiness is a particular threat to forested areas, including, but not limited to deforestation due to agriculture, grazing, development, and logging. As Brazil's population increases (Data Commons), there are concerns about the effects that such growth will have on the Amazon rainforest. Thus, it is reasonable to assume that deforestation could be increasing as the population continues to increase as well. For this reason, we gathered our data from the Acre province, a western area bordering Peru with preserved, undeveloped forest land.

Methodology

In 2014, the Liberal Party of Brazil came into political power, just two years before Jair Bolsonaro's presidency. The Liberal Party and Bolsonaro alike expressed a desire to develop largely forested indigenous land. For this reason we decided to track the changes in vegetation from 2014 to 2021. We processed information through ENVI, with data sourced from the United States Geological Survey's (USGS) EarthExplorer software, specifically from Landsat 8. We tracked changes by comparing data of the same area from 2014 and 2022. Within the ENVI software, we measured the vegetation changes through the Normalized Difference Vegetation Index (NDVI), Green Normalized Difference Vegetation Index (GNDVI), Simple Ratio (SR), and Chlorophyll Index (CI) indices for each year. Once all indices were calculated for each year, we compared each year's indices in order to determine potential patterns.

A particularly useful tool for processing our data was the Band Math tool on ENVI. This tool allowed us to create raster images for our several indices. A benefit of using several indices

is that since vegetation is variable and each indices measures vegetation differently, we can have various perspectives on deforestation in the area. For each of our indices:

The NDVI index is calculated using the following formula:

$$NDVI = (NIR - Red)/(NIR + Red).$$

This formula measures the "chlorophyll pigment absorptions in the red band and the high reflectivity of plant materials in the near-infrared (NIR) band" (ArcGIS Pro) & creates an image showing the presence of vegetation. The resulting image displays objects that reflect red and NIR wavelengths (mainly vegetation) with less intensity (lighter) than objects that absorb red and NIR wavelengths (darker).

The GNDVI index is calculated using the following formula:

$$GNDVI = (NIR - Green) / (NIR + Green)$$

This formula measures photosynthetic activity. By replacing the Visible Red band with the Visible Green band in our NDVI formula, it allows us to examine rates of photosynthesis. As a result, GNDVI gives us the ability to indirectly determine vegetation stress by measuring the rate of water & nitrogen uptake into the canopy layer. The resulting image displays our NDVI image, with emphasis on the variable reflectances in our areas with vegetation (the lighter areas of the image).

The SR index is calculated using the following formula:

$$SR = (NIR / Red)$$

This formula measures the "ratio of light scattered in the NIR and absorbed in red bands" and creates an image showing the presence of vegetation. The resulting image displays objects that reflect red and NIR wavelengths (mainly vegetation) with less intensity than objects that absorb red and NIR wavelengths.

The CIre index is calculated using the following formula:

$$CIre = ((NIR / RedEdge) - 1)$$

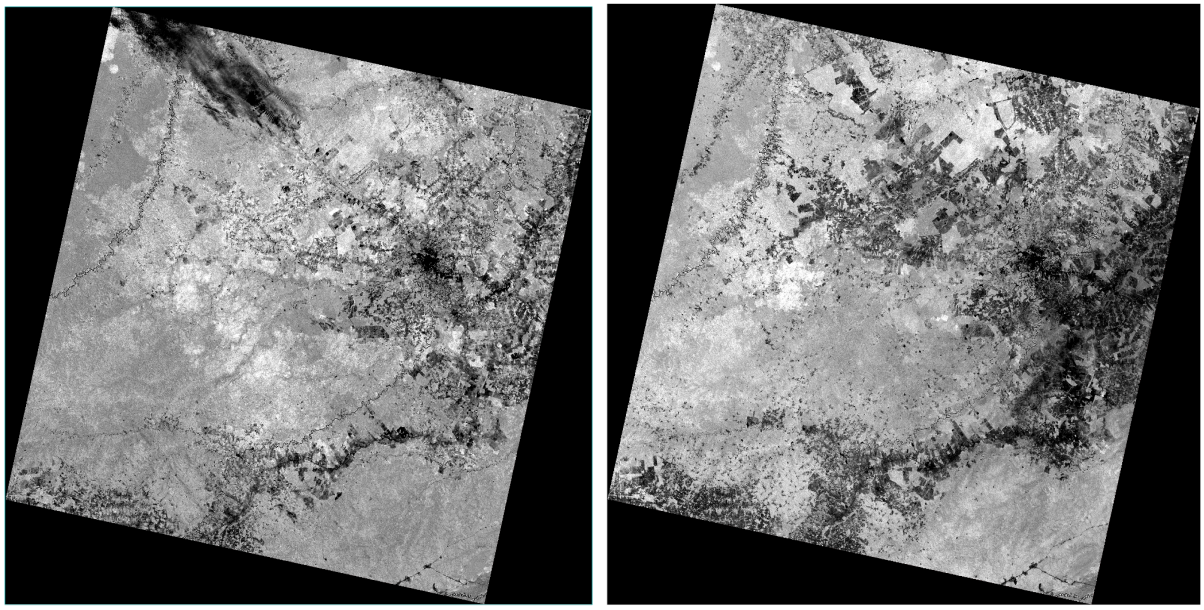
This formula measures "the chlorophyll content in leaves using the ratio of reflectivity in the NIR and red-edge bands" (ArcGIS Pro) creating an image that displays the chlorophyll content. The resulting image displays objects that contain chlorophyll with more intensity than those that do not contain chlorophyll.

To numerically and graphically display the changes in vegetation for each index, we used the Region of Interest tool in ENVI. For each index we created two categories- Forest and Other- with forested regions encompassing areas with high levels of vegetation according to our raster images generated for each index. By using Regions of Interest, we were able to obtain a numerical value for how many pixels classified are vegetation and how many pixels are not included, whether they be farm land, buildings, or roads.

Results

NDVI

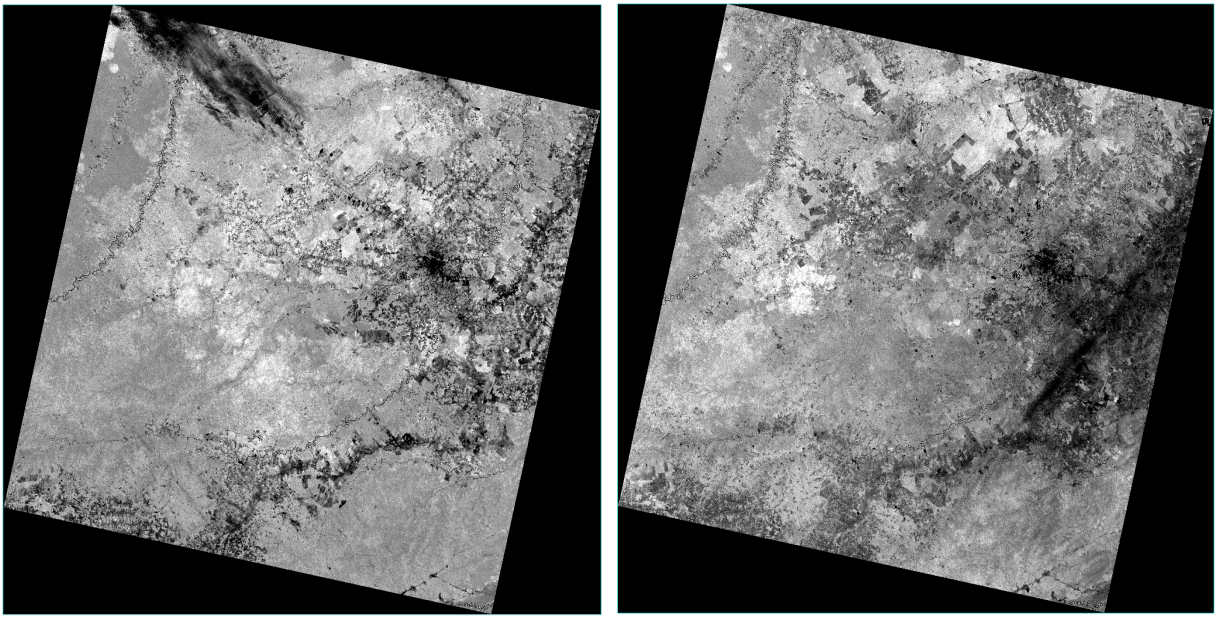
2014 2021



The NDVI images show the change in vegetation range between the two snapshots. There is a clear difference between the two years. A sizable area of the forest appears to have been cleared and replaced with farm plots. In the center, where there once was a forest, are scattered plots of farmland that did not exist prior to 2021. Areas that appear darker have little to no vegetation.

GNDVI

2014 2021

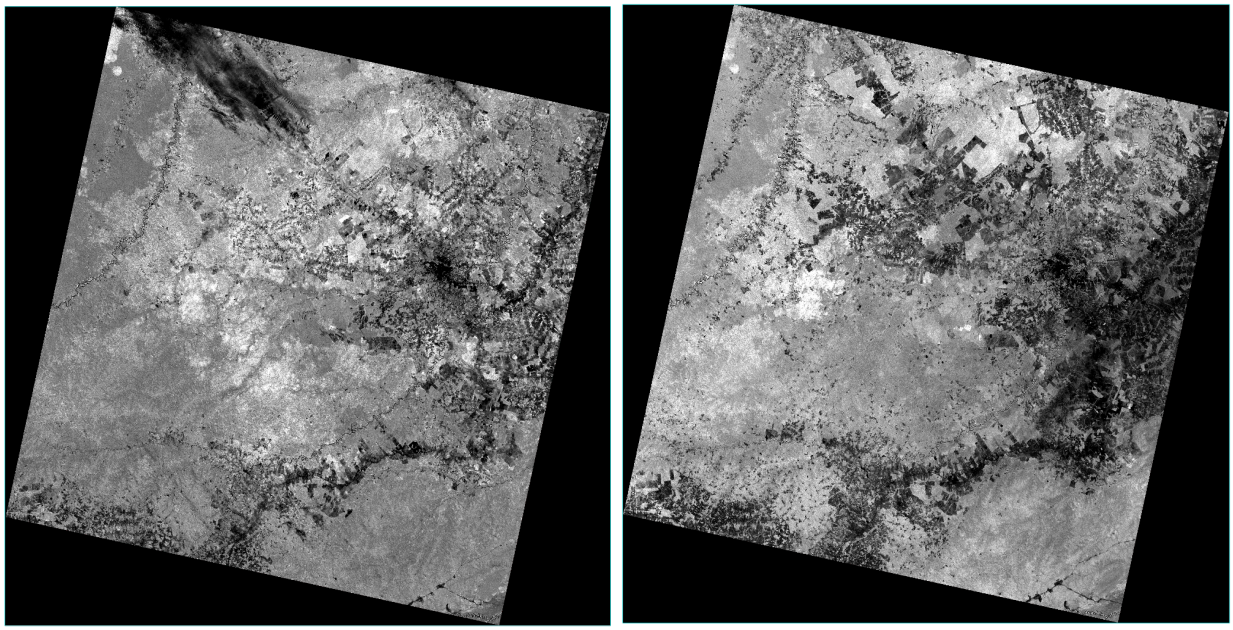


The GNDVI images show a similar change between 2014 & 2021 and in the same areas, though with less distinct differences. Areas where surface change was observed in our NDVI images, such as the central area of the map, are displayed with more intensity (meaning there is less vegetation) in the GNDVI image when compared to the NDVI image. However, we do see a slight shift in the reflectance spectrum for the vegetation found left of center in the image. This

shows that the plant life in this area has a lower photosynthetic rate, and is likely to be under more stress in 2021 than in 2014.

SR

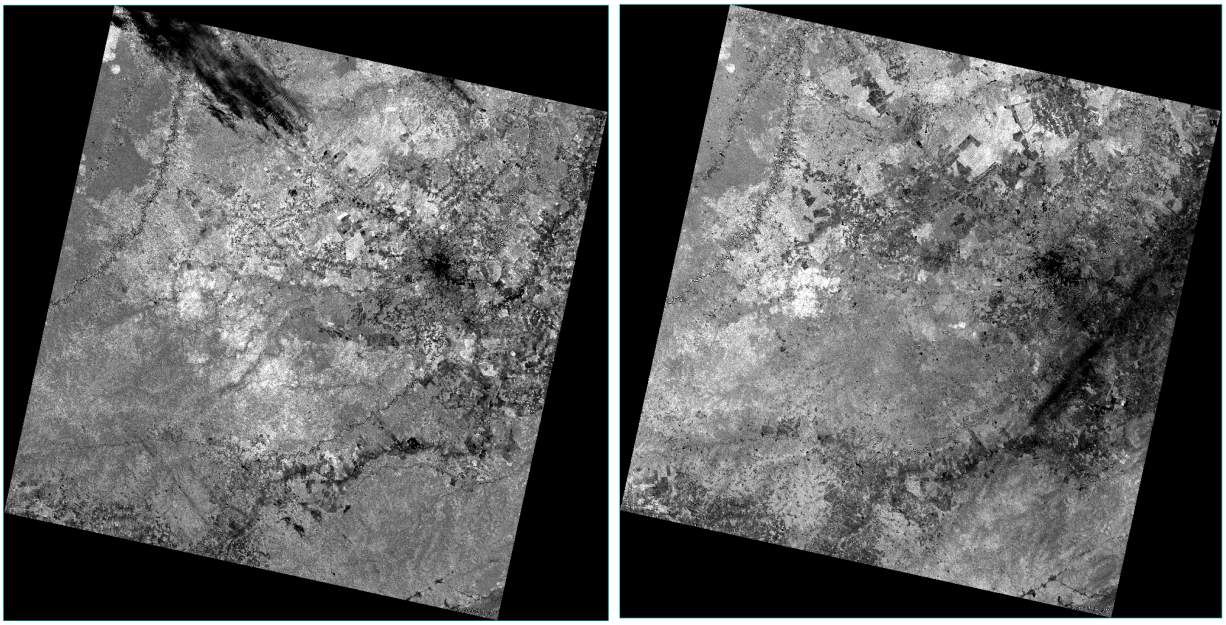
2014 2021



The SR images show the most distinct differences between the two years, and clearly show the plots of farmland that have appeared as a result of deforestation. The spots of farmland previously mentioned in the NDVI section are even more distinguishable in these images. There are also more obvious plots of farmland along the river and towards the top left of the 2021 image compared to the 2014 image. Some of the darker spots in the top right of the 2021 image may be a little inaccurate due to a camera glare that appears to have been factored in.

CI

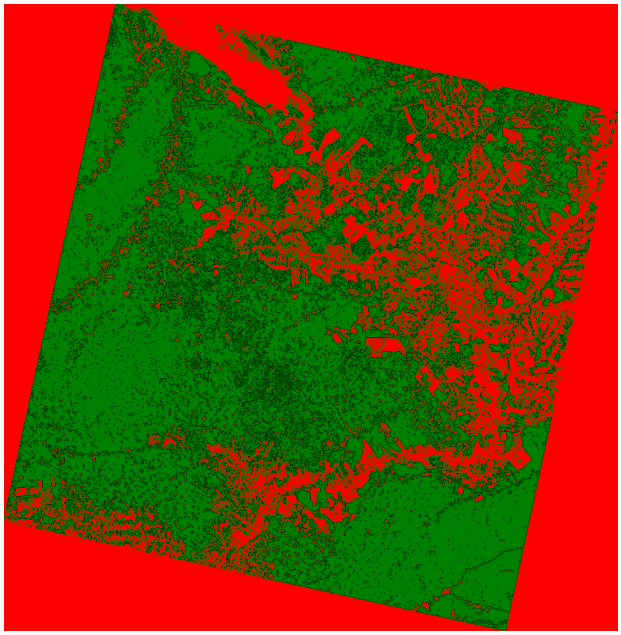
2014 2021



The CI images show a shift in chlorophyll content. Between these years, there seems to be less chlorophyll in the center of the forest overall, with a slight increase towards the top of the image. Similar to GNDVI, the Chlorophyll Index gives us the ability to monitor stressed vegetation in the area. But, CI determines this through the amount of chlorophyll present, rather than photosynthetic rate. Considering that these two indices give us very similar information, this index is supplemental to our GNDVI index, but still shows an increase in vegetation stress to areas proximal to developing farmland.

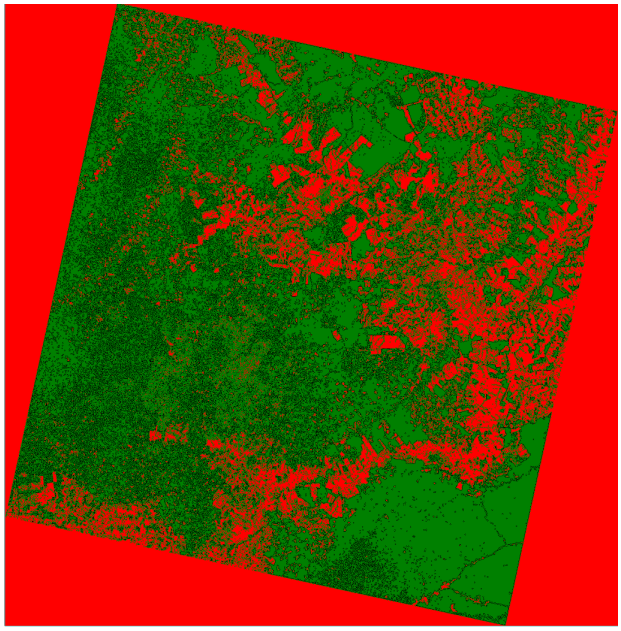
NDVI Analysis

2014



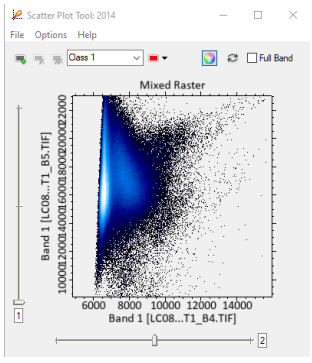
Class Summary	Pixel Count	Percent
Background	18263199	30.917698
Other	10130644	17.150128
Forest	30676528	51.932174

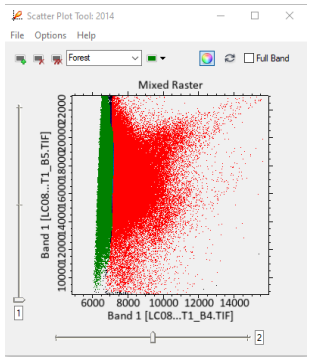
2021



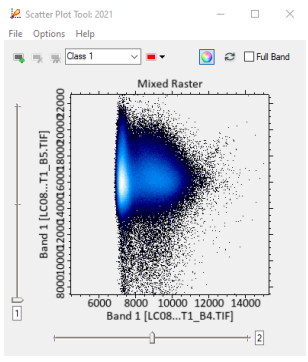
Class Summary	Pixel Count	Percent
Background	18274275	30.936449
Other	12967057	21.951880
Forest	27829039	47.111671

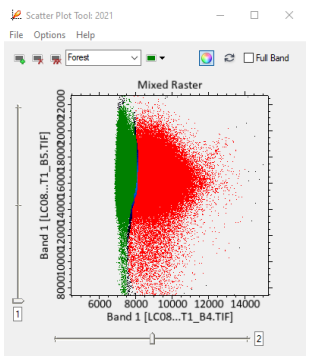
2014





2021





To further analyze our results, we created classification maps that reflect our NDVI index results. To start, a false color image for both 2014 and 2021 was created with Landsat bands 5-4-3. Then, we created scatter plots for 2014 and 2021; comparing band 5 [NIR] on the y-axis

to band 4 [Red] on the x-axis. Analyzing the black and blue scatter plots from the 2 images, a dense white line of pixels can be seen in each. This indicates the pixels reflecting NIR light which is almost entirely vegetation. The pixels extending to the right in the scatter plots represent other land covers that are absorbing the light. Classes were created using the scatter plots of each of these sections: 'forest' in green and 'other' land cover in red. This was then overlain on the map and statistics were generated for overall land coverage and pixel counts. As shown in the percent column, the forest coverage dropped nearly 5% over the 6 years to about 47% of the map. This is extremely substantial given the scope of the map and the short time period.

The two class NDVI analysis shows which pixels were classified as forest and which were not. Visually, we can see that the main chunk of forest in the center and left of this image has been subject to a rapid decrease in vegetation. Numerically, the amount of forest has decreased from 30,676,528 pixels to 27,829,039 pixels, with a decrease of 2,847,489 pixels, or 4.85 percent.

Conclusion

The 2014 to 2021 images for each index shows a noticeable difference in vegetation in our selected area. Visually, there is a decrease in vegetation consistent with each index. As each index displays areas with less vegetation with less intensity, images from 2021 are consistently containing darker areas.

Scatter plots comparing NDVI indices from 2014 to 2021 show a larger density increase of surfaces that absorb NIR light. By creating classes from the pixel wavelengths, the forest and "other coverages" were differentiated and statistics could be analyzed. Despite cloud coverage, the total pixel count shows an approximate 5% decrease in forest coverage in 2021. This equates to 8542.46 hectares or 32.98 square miles of land. Based on the data, there is a continuing trend

of deforestation in Acre. If left unchecked, the remaining acreage of forest in this province could be eliminated completely. Deforestation could also potentially reach a threshold of irreversible ecological damage.

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