Verification of deforestation in indigenous land using satellite image.

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Abstract. Deforestation occurs, in most cases, because of the advance of agriculture, mining and wood extraction, with Pará being one of the states that most deforests, and the Ituna-Itatá indigenous land was evaluated for deforestation for a period of four years (2017/2021). The aim is to make this comparison with NDVI in a geoprocessing software, which used images from the Sentinel-2 satellite. With the results obtained, it can be verified that there really was deforestation within the indigenous territory, in an area of approximately 52 km^2. The largest percentage increase was in sparse vegetation, which means that the forest area became meadow. It can be understood that the NDVI can help governments and other entities to verify deforestation for management assistance.

Keywords. Deforestation, NDVI, Ituna-Itatá, Amazon Forest, Indigenous Land, Satellite.

1. Introduction

The last few years in Brazil have been characterized by deforestation and burning of large areas of the Legal Amazon, which encompasses nine states that are part of the Amazon basin. This large area has regions with similar characteristics and was demarcated for better planning and development, due to the great relevance of the Amazon region for the country. The increase in deforestation in the region is worrisome and often occurs in indigenous lands and conservation units, which have high environmental and social importance.

The year 2021 was one of great area losses, mainly between January and November, when the Amazon Forest lost 10,222 km^2 of forest, an area equivalent to seven times the city of São Paulo [1]. Deforestation on indigenous lands grew by 138% in the period from 2019 to 2021, compared to the previous three-year period (2016 to 2018), according to data from the Prodes program [2].

The deforestation process can be monitored through remote sensing, which is related to images of the earth's surface obtained at a distance [3], and which are acquired by devices called remote sensors. These images are obtained from sensors attached to a satellite. The use of satellite images makes it easier to monitor the territory, which, by methods of local visits, would require very high time and resources.

Vegetation indices are obtained with the spectral reflectance of vegetation in different bands [4], and these serve as an indicator of the presence of vegetation, in addition to indicating its status (biomass and density, for example). Healthy plants are distinguished from unhealthy ones through the specific reflectance of waves, which captured can differentiate them in an image. Vegetation indices are widely used in agriculture, for example, because this way farmers can understand the areas in which they should be more careful. The Normalized Difference Vegetation Index indicates the photosynthetically active biomass, that is, it is an index that allows verifying the health of the vegetation. In the same way that it manages to differentiate plants, this index shows areas of exposed soil, water, dense or sparse vegetation, which makes it possible to verify whether there are areas that have been deforested or not.

In this paper, the study area is the Ituna-Itatá indigenous territory, which has not yet completed its demarcation process, and is in the land use restriction phase. This territory has approximately 1,425.27 km^2 and is located in the cities of Altamira and Senador José Porfírio, in the state of Pará (PA), in the northern region of the country.

The city of Altamira (PA) is the city that most deforested its forests over the last decade (2011 to 2021) and Ituna-Itatá is the indigenous territory that suffered the most from the loss of forest areas. The state of Pará is the second in the Legal Amazon to have the most deforestation in 2021 [5]. According to the Instituto do Homem e Meio Ambiente da Amazônia (Imazon), 69% of the deforested areas are private and the rest occurs in indigenous lands, conservation units and settlements.

There are indications of isolated indigenous people who inhabit the Ituna-Itatá region, but due to the lack of government investments, studies and research in the region have not yet been concluded, making the preservation of the area not permanent, but with an expiration date and in need of renewal. In the case of isolated groups, the Ituna-Itatá region is dependent on ordinances that preserve the region, as a matter of survival for this indigenous people.

Thus, the paper aims to use remote sensing, through the Normalized Difference Vegetation Index (NVDI), which allows the assessment of land use changes in the years 2017 and 2021, and with these changes, monitor the deforestation of the area. The two images, from the two years, were from the month of July, and covered the indigenous land of Ituna-Itatá (Pará - BR).

2. Research Methods

The satellite images used were downloaded already georeferenced and with atmospheric correction from the EROS Science Processing Architecture On Demand Interface (ESPA) website, belonging to the United States Geological Survey (USGS). Within the site, the area of interest was demarcated and images from the Sentinel-2 satellite were chosen, which have a spatial resolution of 20 meters. In the search, two images were obtained, one for the year 2017 and another for the year 2021, both were captured in the month of July of the respective years. The search considered all Sentinel images, from the beginning of its operation, which was in the year 2015 to the current year, 2022, being the oldest image from a period before the current presidential government (2018-2022). A refinement was made in the search so that the results had a cloud cover of less than 20% for the area. With this, the images that had less cloud cover for the same period were chosen, and that could have a better view of the area.

Once the images were downloaded, they were placed in the QGIS software to verify the data. The NDVI was calculated through the "Raster Calculator" function, which resulted in raster-type output files. The multispectral bands 4 and 8 of the satellite were used in the calculation, which are the bands that have the necessary information for the calculation of the index.

The equation used to calculate the NVDI is:

$$NDVI = \frac{NIR - VIS}{NIR + VIS} \quad (1)$$

Where:

NDVI = Normalized Difference Vegetation Index;

NIR = Near Infrared Band;

VIS = Visible Band.

For Sentinel-2 satellite bands, the equation is:

$$NDVI = \frac{Band\ 8 - Band\ 4}{Band\ 8 + Band\ 4} \quad (2)$$

The results of this equation range between -1 and 1, and the values can be divided by classes, as showed in **Tab.1** [6].

Tab. 1 - Classes for Normalized Difference Vegetation Index.

NDVI Classes	Uses
-1 to 0	Water bodies, exposed soil or absence of vegetation
0 to 0.33	unhealthy vegetation, with some kind of deficiency
0.33 to 0.66	undergrowth or sparse vegetation
0.66 to 1	dense vegetation or forest

Source - [6].

Afterwards, a reclassification was performed for these files, since the conversion of the raster with NVDI values to vectors is only possible with integers and the raster is in floating point. This was done using the GRASS complement function (r.recode) for the images of each year. The conversion to vectors allows statistics to be made for the dimensions of the areas, allowing results to confirm the increase in deforestation for the study area during the period. With the conversion made, the areas for the years 2017 and 2021 were calculated.

3. Results and Discussion

The results of the variation during the period 2017 and 2021 can be seen in **Tab. 2**.

Tab. 2 - Variation in the areas between 2017 and 2021.

Class	Area (km^2)		Increase	
	2017	2021	(km^2)	(%)
Water/Exposed Soil	0.05	0.016	-0.034	-68
Unhealthy Plant	4.34	3.83	-0.51	-11.75
Sparse Vegetation	24.41	76.97	+52.56	+215.32

Dense Vegetation/ Forest	1,395.76	1,343.75	-52.01	-3.73

It can be stated that there was a decrease in forest areas, which corroborates the analyzes carried out by INPE [7]. There was a 3.73% decrease in the area, which corresponds to 52 km^2, while the increase in sparse vegetation, which is the area that was deforested to become pasture or mining area, increased by 52.56 km^2. As a percentage, there was an increase of approximately 215 percent of deforested area within an area of indigenous territory during the period, which can be considered a very high level of deforestation for a period of 4 years, which if it continues at the same rate growth rate can generate a very large environmental imbalance in the region and in nearby regions.

Classified maps were also generated for the two years (2017 and 2021), in which it is possible to notice the difference between the years of analysis. In maps, a greener color refers to forests and more orange and yellow colors are the areas where deforestation occurred **Fig. 1**. There is a decrease in areas of dense vegetation, mainly in areas of unhealthy vegetation, such as pasture or agriculture. The software map can also be compared with Landsat/Copernicus satellite images of the area for the respective years **Fig. 2**, which corroborates the data in **Fig. 1**.

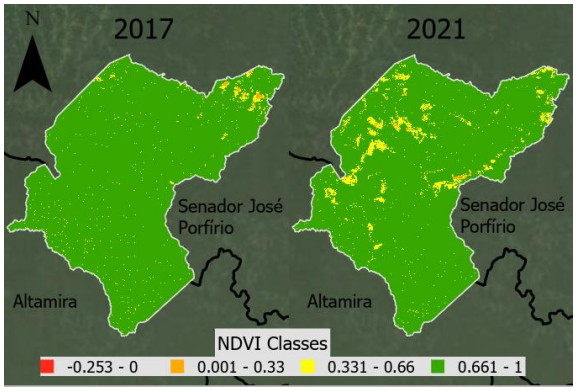

Fig. 1 – Normalized Difference Vegetation Index classes for the area.

Fig. 2 – Satelitte Image for the area in natural color for 2017 and 2021.

These results have a meaning, and several factors may be contributing to this increase in deforestation in inappropriate areas: it reveals the disregard for the work of researchers in the indigenous area studied, since an area considered relevant by the researchers is not important to the government; there is a collective sense of impunity, as the wrong sense of justice makes those who destroy the forest think that they will never be punished for deforesting in illegal areas; the advance of agriculture, mining and wood extraction in Amazonian territory, carried out in a greedy and disorderly way, does not respect limits, since the inspection by the public authorities is ineffective and precarious for regions like these, which are often isolated and far from major urban centers.

Finally, the form of organization of the territory, as well as the development, must be rethought, so that it is done in an orderly, responsible, and socially and environmentally correct way. And with the help of technologies, all this planning is facilitated, with just a few steps of the public power for decision making.

4. Conclusions

At the end of the analyzes carried out, with the results obtained with the NDVI calculation, it can be seen that the areas of dense cover/forest are well delimited and recognized, as well as the areas of exposed soil and water. Intermediate values between 0 and 0.66 are most often assertive, but it is not possible to say whether some of the areas have exposed soil or are areas with sparse vegetation (grasses). Confirmation of some specific points must be done with the aid of observation of satellite images for the area on the chosen date, if the objective is to do a very specific and accurate job of mapping land use.

It is possible to say that the analysis of land use changes, carried out with the help of NDVI, is of great importance in aiding planning and decision-making by governments and other institutions interested in the subject. Satellite imagery reduces the time needed to track changes that are taking place over time. A few years ago, land use mapping was carried out with field visits and images captured from airplanes, for example. This required a lot of planning, execution and processing time for the data obtained. With the use of satellite images, monitoring is almost done in real time and in much less time, since all you need is a computer with internet access and the images of the place you want to study.

The results found show that there really was an increase in deforestation within indigenous territory. Despite the decrease in forest areas, in percentage, they were not so high (around 3.7%), the area in square kilometers shows that these areas were transformed into pasture or sparse vegetation, which means 52 km^2. The analyzes performed using NVDI were satisfactory to confirm deforestation in the region during the period studied.

Deforestation of areas that should be preserved is an issue that deserves attention, as it occurs in a disorganized and often illegal manner. These deforestations sometimes generate conflicts

between native peoples and miners or farmers in the region, and such analyzes can help the government to locate the most relevant regions so that irregularities do not occur again.

5. References

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